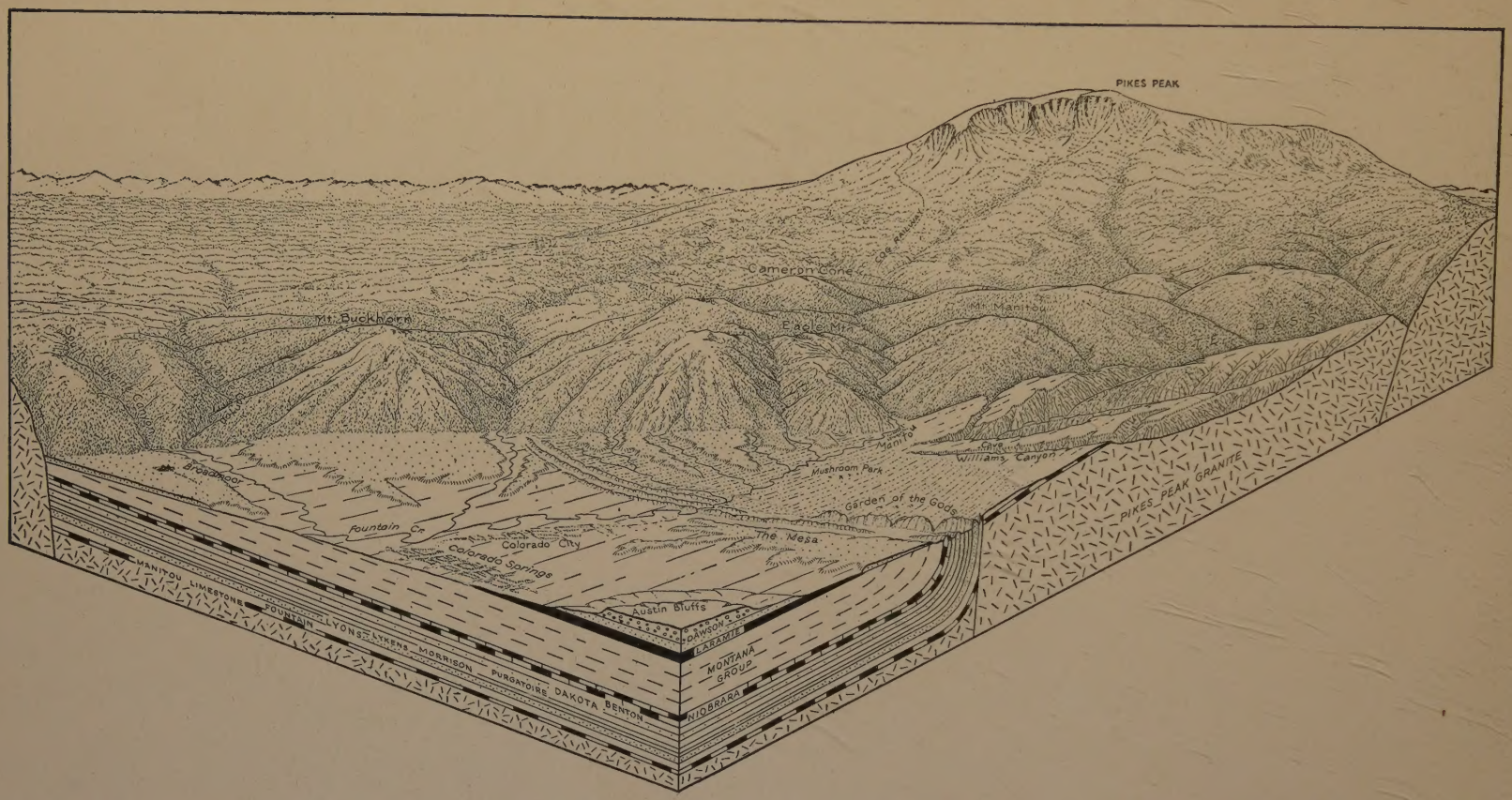
16 sq

12 sq.

BLOCK DIAGRAMS



Frontispiece

Block Diagram of the Colorado Springs and Pikes Peak district, Colorado. The drawing shows the crystalline mass of the Rockies with the even surface of the Rocky Mountain upland surmounted by the monadnock mass of the Pikes Peak Range. In the foreground are the almost horizontal strata of the plains, strongly upturned by a fold to form the hogbacks in the Garden of the Gods. The hogback ridges trend southward and are cut off at the base of the mountain mass by the Ute Pass fault. Consult the Colorado Springs Folio, U. S. Geological Survey, No. 203, for complete description of this region.

BLOCK DIAGRAMS

AND OTHER GRAPHIC METHODS USED IN GEOLOGY AND GEOGRAPHY

966

BY

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PREFACE

READERS of this book may well be pardoned if they feel that its author has been presumptuous in attempting to tell how block diagrams are made when masters in the art of graphic expression have thus far left this duty almost unfulfilled. Perhaps a more reasonable and kindly attitude of mind will be engendered if those who use this book are immediately brought to realize the spirit which prompted its preparation. It was certainly not undertaken because of a desire on the author's part to present to the public some faultless examples of the draftsman's art. The aim of the book is rather to direct the stumbling beginner along that same stony path which has furnished the author so many exasperations during several years. It may be that the cause of many painful falls can be pointed out and the path thus made easier. Let us hope at least that as many as possible of the useless and tiresome journeys off of the direct route may be prevented. Realizing, then, that the slight facility of expression which may be found in these pages has been acquired gradually only during a long period of awkward experimentation, the student may perhaps be made more willing himself to attempt an effort in this direction even though at first he comes far from realizing his hopes.

Thus, the function of this book is, first, to present all the helpful hints which the author has been able to assemble, and second, to offer a touch of personal encouragement to the student in the endeavor to sustain him during those periods when the results of his efforts do not seem to justify the agony which he is experiencing.

In order to accomplish this purpose the book deals not solely with the art of graphic expression. In addition, some attention is given to the content of physiography and geology. This is done because it is just as necessary to be familiar with the ideas to be expressed as to be familiar with the technique of expression. The fact is that it is impossible to discuss one without the other. Therefore, the subject matter of this book has been arranged to conform largely with the subject matter of physiography and geology. This is especially true in the first part, which is devoted to the presentation of land features. In depicting landscapes in block drawings, detailed precision of form and mathematical exactness of position is not necessary, nor even desirable. Yet it is essential that the simple rules of perspective be not violated. Reliance upon perspective methods is especially necessary in the portrayal of features so varied in form as most landscapes are.

Nor is the use of perspective so puzzling as at first appears, if the student mentally transform the apparently disordered mass of topographic features which make up

59232

most landscapes into simple geometrical designs which lend themselves readily to perspective treatment. Thus, rectangular blocks, cubes, cones, pyramids, disks, cylinders, half cylinders, truncated and inverted cones and pyramids, even spheres and ellipsoids, may be made to take the place of mesas, buttes, plateaus, ridges, anticlinical mountains, volcanoes, matterhorn peaks, glacial troughs, cirques, rounded mountain masses, and the great array of topographic details which otherwise seem to have no particular shape.

Chapters II and III, of Part I, are therefore devoted to the elucidation of the simple principles of perspective and to the representation of variously shaped blocks which later are to be used as the solid mass from which intricate landscapes are to be carved, much as statues are carved from blocks of marble. The successive chapters in Part I take up, then, the various land forms, first treating the constructional forms: plains and plateaus, dome mountains, folded mountains, block mountains, and complex mountains. The destructional forms are next considered under the head of the chief destructive forces which produce them, namely: streams, glaciers, and waves. Each type of land form is developed at first as an ideal one, and the confusing details and irregularities usually found in nature are omitted in order that simplicity may be gained. But after this is accomplished each type is further explained by the representation of certain selected regions. Representative maps, from both Europe and the United States, are transformed into block drawings. Indeed, this phase of the work, that is, the portrayal of actual regions, is deemed the most important. It is important to the teacher who wishes to present before his class a visual impression of a map which is being studied in order to explain its topography and structure. It is likewise important to the geologist, the consulting engineer, or expert who has to prepare a report on an area which he has studied, for a board of managers not always familiar with the technical aspects of the problem. That is to say, the ability to represent actual areas rather than imaginary type forms is an asset which the student has every reason to cultivate.

In the second part of the book attention is given to the use of graphic methods in the solving of geological problems involving the accurate determination of strike, dip, extent and location of outcrop, depth to known formations, and other data frequently demanded in engineering and geological work. This, of course, requires accurate methods. The isometric type of perspective drawing is therefore explained and several typical problems are presented and solved.

The third part of the book relates to special methods and the preparation of more elaborate types of diagrams.

The fourth part contains a few suggestions of value to the geographer. Sketches and diagrams represent by symbols the various kinds of land utilization. Brief consideration is also given to the making of line drawings from photographs, and the preparation of sketches in the field.

The fifth part of the book introduces some hints on crystal drawing, following to some extent the methods elaborated by Dana and Penfield, but at the same time suggesting a simpler lay-out for the crystal axes.

It is hardly necessary to say that the student will gain ever so much of practical value and of inspiration if he will critically examine and be guided by the work of such masters as W. M. Davis, W. H. Holmes, de Martonne, Heim, and

other artists who have enhanced many of our geological and physiographical texts. A number of drawings by Davis and by Holmes are therefore reproduced in this book and a list of references at the end will guide the reader to additional examples of their work and to many other helpful sources.

It is always a pleasure to acknowledge the encouragement I have received from my teachers and friends at Columbia University. Professor D. W. Johnson, by his advice and example, ever incites a love for the highest standards of excellence. My close association with Frederick Morris, now with the American Museum of Natural History, and with Professor S. H. Knight of the University of Wyoming, both men of distinct ability in the preparation of block diagrams, will always be remembered as a source of great profit. I am glad too, to acknowledge the very special encouragement offered me by Dr. Isaiah Bowman of the American Geographical Society of New York during my association with that organization at the time of the Paris Conference. My thanks are due also to Professor E. B. Mathews of Johns Hopkins University, who loaned me from the library of that institution a copy of Dufour's thesis referred to in Part II of this book. Not the least deserving of mention are the many splendid students who, as the subjects of my experiments while working out a scheme for the presentation of this material, have contributed much in the way of kindly criticism and help.

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September, 1924.

ACKNOWLEDGMENT OF ILLUSTRATIONS

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W. M. Davis, Geographical Essays, Ginn & Co., Figures 165, 166, 167, 246, 247, 248, 249, 250.

W. M. Davis, Handbook of Northern France, Harvard University Press, Figures 230, 231.

W. M. Davis, Erklärende Beschreibung der Landformen, Figures 150, 160, 161, 162, 173, 176, 251.

W. M. Davis, The Colorado Front Range, Annals Assn. of Am. Geog., Figures 252, 253.

J. K. Finch, Topographic Maps and Sketch Mapping, John Wiley & Sons, Figures 233, 234, 238, 240, and 244.

L. C. Grieves, Military Sketching, U. S. Infantry Association, Figures 232, 235, 236, 237, 241, 242.

D. W. Johnson, Shore Processes and Shoreline Development, John Wiley & Sons, Figure 175.

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C. R. Miller, Figure 270.

U. S. Geological Survey, Figures 60, 131, 254, 255, 256, 262, 264, 267, 268, 269.

U. S. Hydrographic Office, Figures 132, 133.

CONTENTS

		PAGE
PREFACE		v
PART I.	BLOCK DIAGRAMS OF LAND FORMS	
CHAPTER		
I.	INTRODUCTION	1
II.	ONE-POINT PERSPECTIVE	5
III.	TWO-POINT PERSPECTIVE	22
IV.	PLAINS AND PLATEAUS	29
V.	DOME MOUNTAINS	53
VI.	FOLDED MOUNTAINS	62
VII.	BLOCK MOUNTAINS	76
VIII.	COMPLEX MOUNTAINS	89
IX.	VOLCANOES	93
X.	STREAMS	97
XI.	GLACIERS	109
XII.	WAVES	115
PART II.	ISOMETRIC DIAGRAMS AND PROBLEMS IN STRUCTURAL GEOLOGY	119
PART III.	SPECIAL METHODS AND THE MORE ELABORATE TYPES OF DIAGRAMS	151
PART IV.	LANDSCAPE SKETCHING	165
PART V.	CRYSTAL DRAWING	189
	REFERENCES	199
	INDEX	203

BLOCK DIAGRAMS

Part I

BLOCK DIAGRAMS OF LAND FORMS

CHAPTER I

INTRODUCTION

1. Purpose.—Block diagrams have a two-fold function: First, to present pictorially the surface features of the ground; and second, to represent the underground structure. Unlike maps, which represent the surface only, and geological cross-sections, which represent the structure only, a block diagram represents both the surface and the structure at the same time. In addition to this, the surface view and the structural view are placed properly with regard to each other, so that the reader can, with the greatest ease, see wherein the topography is determined or affected by the formations beneath the ground.

Moreover, the block diagram does not attempt to portray all the confusing and distracting details, which the map, by its very nature, would have to indicate. The block diagram selects just those elements to which attention is to be directed. While, to this extent, it is lacking in accuracy because it does not convey the whole truth, it is not therefore any more to be condemned than is any generalized and simplified statement which is later to be elaborated. It is by this elimination of irrelevant facts, and by the exaggeration of the pertinent ones, that the block diagram conveys to the reader a clean-cut idea, clearly and easily apprehended because of the interesting manner in which it is presented, and readily retained because of the visual impression which has been produced.

A block diagram presents the relationship between the surface of the ground and the underground structure by representing an imaginary block cut out from the earth's

crust. The top of the block gives a bird's-eye view of the region, and the sides of the block its underlying geological structure. A block diagram thus gives a three-dimensional picture, whereas a map or a geological cross-section gives only a two-dimensional one. While this three-

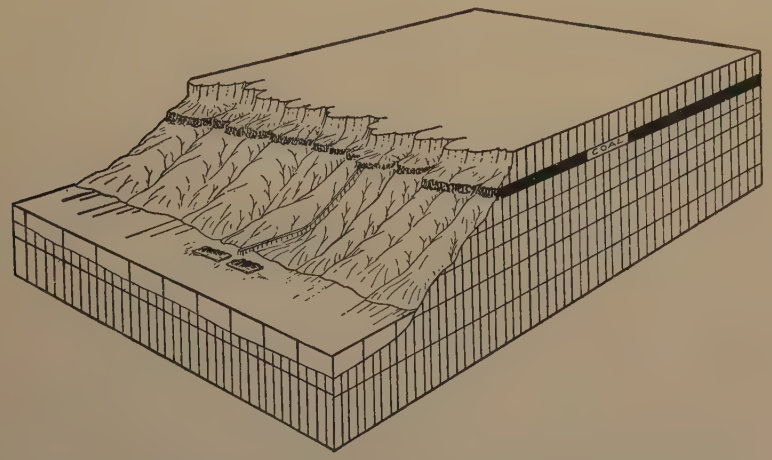


FIG. 1.—A block diagram to illustrate the purpose of block-diagram presentation. The surface of the ground and the internal structure of the region are presented in the same view. The relation between surface and structure may thus be readily noted. This view represents one side of a river valley cut below the Allegheny plateau. The rocks of the plateau are horizontal beds. One of them is a coal seam outcropping near the top of the valley wall. The ease of mining coal beds of this kind is suggested by the chute from the tunnel opening above to the coal barges below.

dimensional expression is immensely to be desired in bringing out the intimate relation which exists between surface form and underground structure, it is occasionally helpful simply as a means of conveying to the reader the intricate nature of the surface forms themselves, a task which the best map sometimes fails to accomplish even for the proficient map reader.

A block diagram owes its value to the ease with which it can be understood. The reader makes immediate acquaintance with it because there is nothing unusual about it. No conventions are needed to represent the topography. No explanation is needed to indicate the position of the geological cross-section. It carries its message directly to the eye and leaves a visual impression unencumbered by lengthy descriptions. Thus Fig. 1 shows how flat-lying bituminous coal beds, outcropping well up on the valley sides of the Allegheny River, are exploited by horizontal drifts, or tunnels, the coal being then sent by a chute to the barges lying below.

2. Bird's-eye views.—The surface of a block diagram usually represents a bird's-eye view of a region. It may show a great expanse of country as if viewed from a very high point, as in Fig. 2, or a much more restricted area as if viewed from a lower elevation, perhaps even lower than some of the features shown in the block, this being the case in Fig. 3. Sometimes it is only the views of the topography which are desired and no need is felt for any explanation of the underground structure. In that case, any part of the upper surface of the block may be cut out to form a picture. The edge of the picture may be considered the sides of a window through which the landscape is observed. The rectangular frames in Figs. 2 and 3 indicate this relationship.

It is thus to be noted that a bird's-eye view does not differ from an ordinary picture except as to the height of the observer above ground, and that both the bird's-eye view and the ordinary picture may be related to, and in

fact may be transformed into, some block of the earth's crust of which each is only a part.

3. Using only parts of a block.—Most block diagrams, untrimmed as to their corners, are awkward lozenge-shaped figures. These take up much room on a page. Most of the actual value of the block lies in its middle portion, thus permitting the corners to be eliminated without disadvantage to the drawing. This may be done by cutting off the corners and preserving the general character of the block, as in Fig. 4, or by viewing the block through a rectangular frame which hides the extremities, as in Fig. 5. A drawing of this last type suggests very slightly its derivation from a block, but it is well to keep in mind the fact that its preparation demands the same methods that a complete block would require.

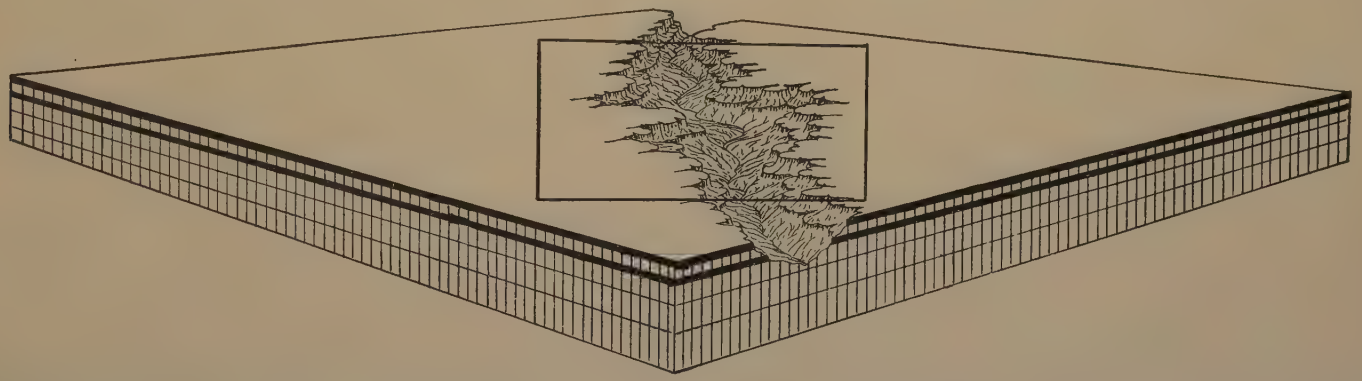


FIG. 2.—Block diagram to represent bird's-eye view of a canyon. The point of view is far above the canyon. Part of the surface of the block is marked off by a rectangular frame to suggest that such a view of a canyon can really be considered part of a block diagram. It may be noted, therefore, that the methods used in block-diagram drawing are applicable also to the drawing of ordinary landscape sketches.

4. The details of the drawing.—In the preceding paragraphs we have called attention to the larger elements of the block diagram and have suggested the value of relating all diagrams of whatever shape, and even sketches which do not include cross-sections, to some block as a basis. In this way the simple principles of perspective controlling the drawing can more readily be kept in mind.

In the same manner the numerous topographic details which make up a drawing can be better represented if they likewise are related to geometrical solids to which the rules of perspective can be applied. Thus, rectangular and triangular blocks, pyramids, cones, hemispheres, and cylinders are easily drawn in perspective, and when deprived of their angular or severe character by a few judicious strokes, are made to represent mesas, and buttes, ridges, mountain peaks, volcanoes, and other features. Indeed, there is no topographic form which cannot be related to a simple solid and as a consequence more easily drawn. An analysis, along the lines suggested, of any landscape to be

represented, is therefore fundamental to good work in block-diagram presentation.

5. Summary.—The preceding paragraphs teach us that all sketches and bird's-eye views, as well as block diagrams, may be thought of as related to some block as a basis, even though their appearance on the page, with their sharp corners trimmed off, may somewhat disguise this important fact. We learn also that all landscapes may be resolved into details of simple geometrical form, more readily drawn in perspective than the intricate forms of nature. It is therefore necessary at the outset to become familiar with the principles underlying the construction of the block. Then, as the work progresses, these same principles can be applied to the drawing of geometrical solids and the elaboration of the detailed forms.

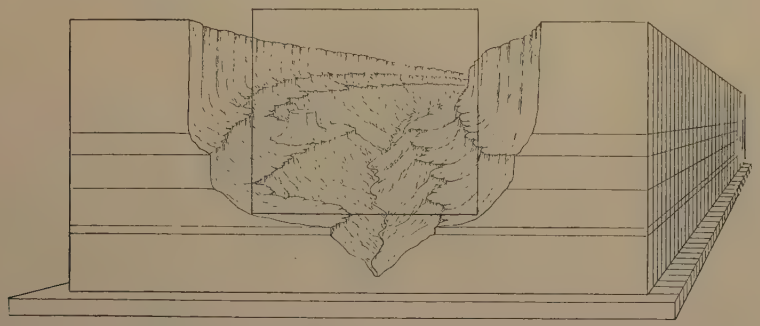


FIG. 3.—Block diagram representing view of a canyon. The point of view is intermediate between the top and bottom of the canyon. This is to show that block diagrams need not always represent views seen from far above. The observer may actually be below part of the scenery. The picture included within the rectangular frame is like any picture taken from within canyon walls. This drawing suggests, too, that any similar picture can in turn be transformed into a block diagram either by adding to it or trimming it off.

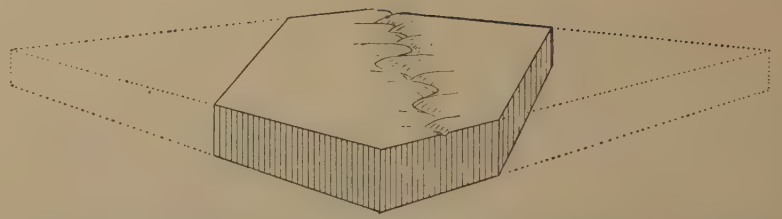


FIG. 4.—A lozenge-shaped block (shown by the dotted lines). This is the usual appearance of a rectangular block when drawn in perspective. The solid lines represent part of the same block deprived of its long extremities. This is to show that blocks may be drawn to any shape, but that if any particular shape is desired it is best derived by trimming off the corners of rectangular blocks drawn in conformance with the usual rules of perspective.

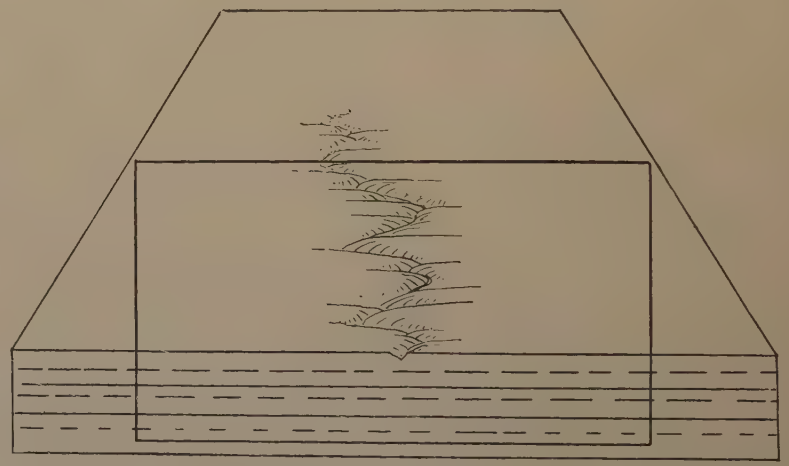


FIG. 5.—A block drawn in perspective. Part of the block is included within a rectangular frame. This is the useful part. The rest is to be eliminated. Thus a rectangular drawing, better accommodated on the printed page, may be prepared from a larger block.

CHAPTER II

ONE-POINT PERSPECTIVE

6. A simple rule.—For many purposes, a very satisfactory block may be drawn simply by making the back of the block narrower than the front. It is obvious that if the sides of the block are drawn parallel with each other the perspective effect is not produced and the result is unnatural in appearance (Fig. 6, block *A*). The block

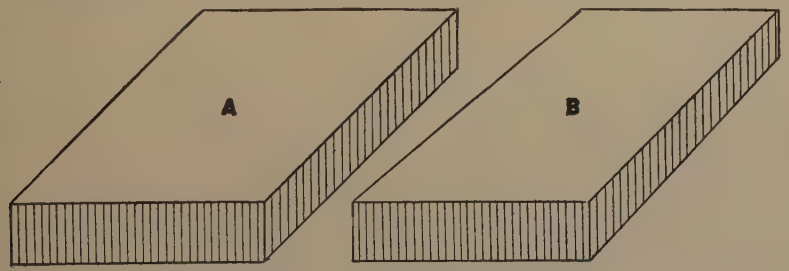


FIG. 6.—Two blocks. Block *A* is incorrectly drawn; block *B* is correctly drawn. In block *A* the lines of each set are drawn parallel to each other. In block *B* the lines at the sides converge in going away from the observer. This illustration is to show that for simple drawings hardly any knowledge of perspective is necessary. Only draw the back of the block narrower than the front.

seems to be spreading out in the distance. By allowing the side lines to converge gradually in going away from the observer, a better effect is secured (Fig. 6, block *B*).

7. A precaution.—It is well to note, however, that the drawing of the back line of the block shorter than the front line is a rule to be universally followed only if the front of the block faces the observer squarely. It frequently happens that, in the case of a block which has the corner pointing toward the observer, the line farther away is longer than the corresponding line near the front of the drawing, though both represent lines of the same length in the object itself. Thus, in Fig. 7, the line *AB* in each block is longer than the line *CD* in the same block, whereas in each case *AB* equals *CD* in the object. Blocks placed in this position, not facing directly toward the observer, should therefore be drawn with close regard for the principles of perspective, because it is otherwise difficult to draw the various lines to their correct relative lengths. The drawing of blocks in this position is explained under Section 22.

8. Some simple blocks.—Observing now the simple formula of drawing the back of the block narrower than the front of the block in case one end of it faces squarely toward the observer, let us present an array of simple blocks thus drawn (Fig. 8). Each of these blocks looks natural when used alone. But it will be noted that if two of them are used together, as if they represented adjacent regions, a certain awkwardness is apparent (Fig. 9). In this figure, block *L* seems to be tilted up at a higher angle than block *K*.

9. A rearrangement.—If the miscellaneous array of blocks shown in Fig. 8 is rearranged so that all of the blocks

seem to be parts of one great plane, as in Fig. 10, it will be noted then that their bounding lines, in tapering backward, all seem to converge toward one point in the distance.

10. One-point perspective defined.—A system of perspective in which one set of lines converges toward a distant point, and the other lines are horizontal or vertical, is termed the one-point system or one-point perspective. There is only one vanishing point.

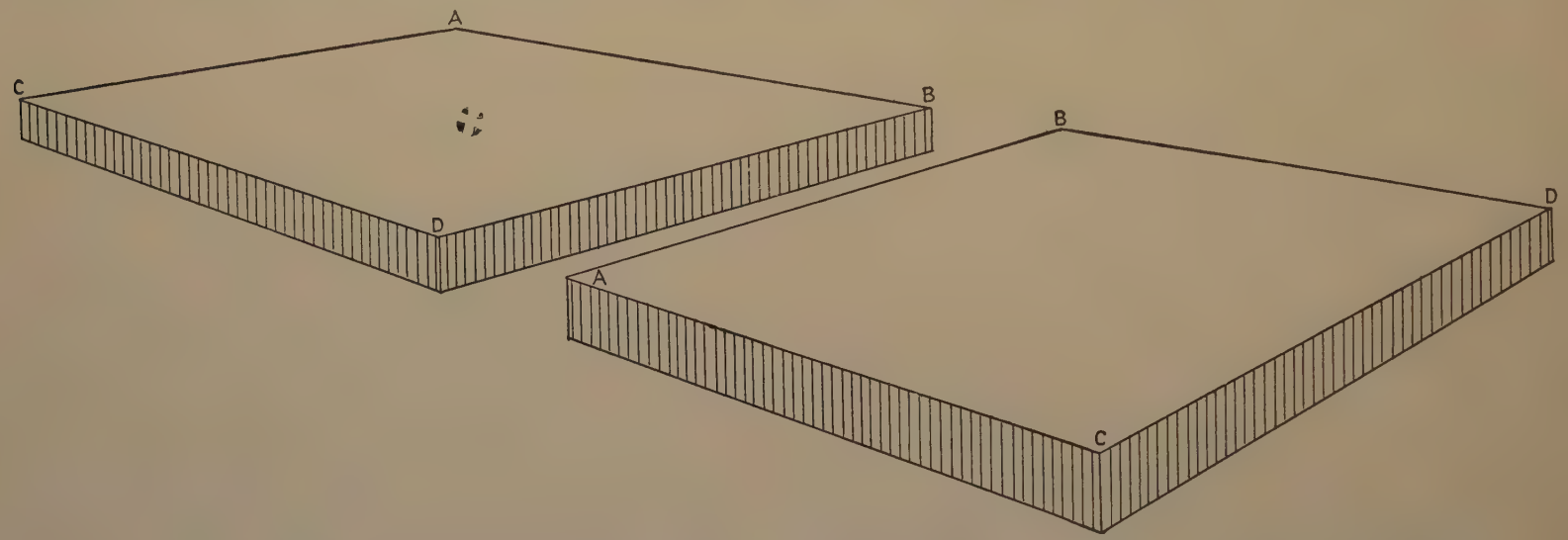


FIG. 7.—Two blocks in perspective to show that the side of a rectangular block farthest away from the observer is not always drawn shorter, as was done in Fig. 6. In each of the blocks in Fig. 7 the line *AB* is longer than the line *CD* of the same block, though in each case it is farther away from the observer. This is often true in the case of blocks having a corner pointing to the observer. Hence the drawing of such blocks must follow certain rules of perspective, whereas in drawing blocks with one end facing squarely toward the observer, this is not always necessary.

11. Drawing a rectangular block in one-point perspective.—To draw a block in one-point perspective, select some point near the top of the sheet of paper. From this point, with pencil and ruler, draw two radiating lines downward (Fig. 11, *A*). Then complete the front and back of the block by drawing horizontal lines *LM* and *NO* (Fig. 11, *B*). For the front end of the block draw another horizontal line *PQ* (Fig 11, *C*), and complete by drawing the vertical edges *NP* and *OQ* (Fig. 11, *D*). To draw the side of the block that is visible to the observer, draw its bottom edge from the point *Q* to the vanishing point in the distance, and complete by dropping a vertical line from the point *M* to represent the farther corner of the block (Fig. 11, *E*).

12. Drawing several blocks in one-point perspective.—A single block like the one just drawn is essentially a part

of a much larger block, such as Fig. 12. The larger block, however, may be cut up into any number of pieces by means

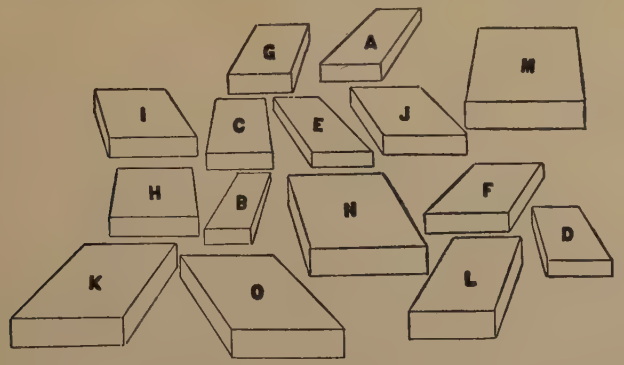


FIG. 8.—An array of rectangular blocks, all having one end facing directly toward the observer and drawn according to the principle that the back of the block should be narrower than the front. This principle is all right when applied to single blocks, but other rules are necessary when a number of blocks are drawn and all are supposed to be lying in the same plane. The blocks shown above seem to be sloping at various angles.

of lines drawn to the vanishing point in the distance and other lines drawn horizontally, as in Fig. 13.

FIG. 9.—Two blocks selected from Fig. 8. Each of these blocks taken separately makes a satisfactory impression, but they do not go well together. At least they do not look as if they were cut out from the same horizontal plane. Block *L* seems to be tilted up more than block *K*.

It will be evident that each of the blocks, *A* and *C*, which lie to the left and to the right of the center, has two faces visible, in addition to the top surface. In each case, one full end face is provided without any distortion, in addition to the side face, which is considerably foreshortened, owing to the perspective. Blocks of this type, that is, blocks lying to the left or right of the center (Fig. 13, *A* and *C*), are therefore more useful than those which lie in the middle (Fig. 13, *B*), and which therefore present only one end of the block to

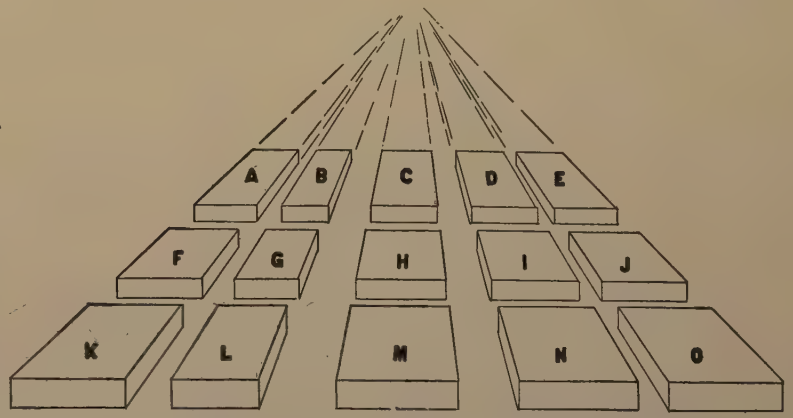


FIG. 10.—The blocks represented in Fig. 8 have been rearranged so that they seem to lie in one plane. When this is done it is noted that their bounding lines, in tapering backward, converge toward one point in the distance, the so-called vanishing point. Only when this is true do the blocks seem to lie flat and in the same plane.

view. When we remember that one of the objects of a block diagram is the presentation of underground structure by means of a cross-section, it is obvious that the blocks farthest toward the sides are the most useful. Thus, in Fig. 14, block *A* is more serviceable than block *B* because the side face of block *A* presented to the observer is larger and less distorted than is the side face of block B.

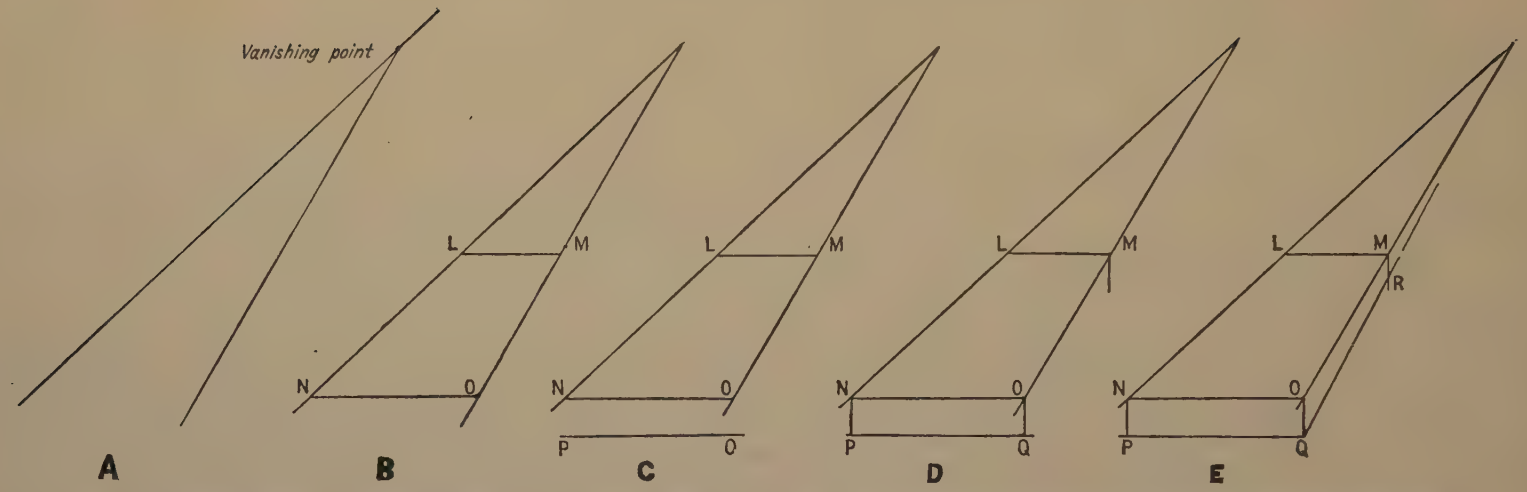


FIG. 11.—Several stages in drawing a block in one-point perspective. The different steps are fully explained under Section 11 of the text.

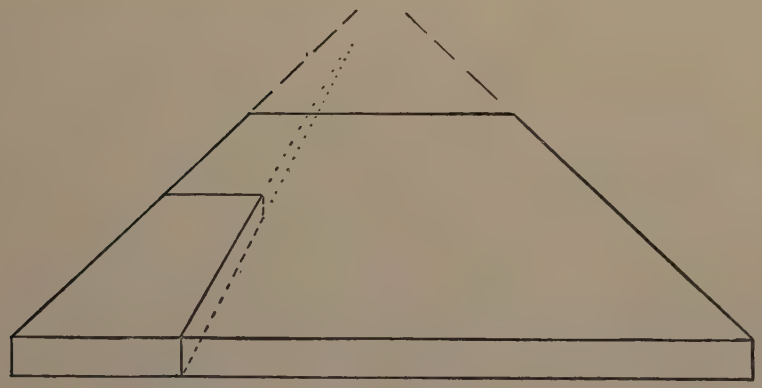


FIG. 12.—Drawing to show that a block like *E* of Fig. 11 can be considered as part of a much larger block.

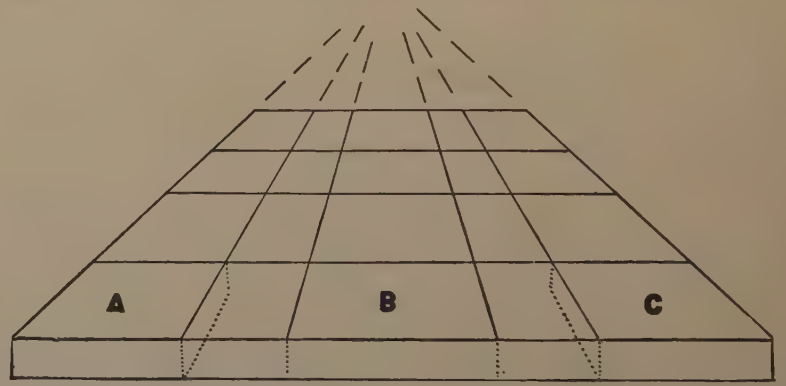


FIG. 13.—Drawing to illustrate the fact that a large block like that in Fig. 12 can be cut up into a number of smaller blocks, *A*, *B*, and *C*, all parts of the same one-point perspective system. This drawing also shows that the two blocks *A* and *C* have two side faces visible besides the top and are consequently apt to be more useful where structural cross-sections are to be shown than blocks like *B*, which presents but one end to the observer owing to its position just under the vanishing point.

13. Drawing the geological cross-section.—When the geological cross-sections are to be drawn upon blocks like those shown in Fig. 14, it will be noted that a block like *A* proves to be a much more satisfactory selection than a block like *B*. The drawing of the section on the end face of the block, in full view, offers no difficulty; the section is drawn

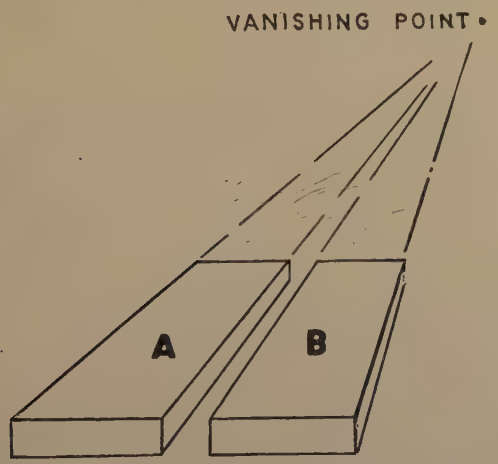


FIG. 14.—Two blocks in one-point perspective. Block *A* is more useful than block *B* because it is farther over to one side of the vanishing point and therefore presents a wider cross-section on its side than block *B* does.

quite in the ordinary way. On the distorted side face of the block, however, the section is drawn as it would appear in perspective. For instance, imagine in Fig. 15 that the geological section *ab* is to be drawn on the end of the block and that section *bc* is to be drawn on the side of the block. Section *ab* is transferred outright without any change. If necessary, it may be reduced or enlarged, but its details are not altered in their relative positions. Section *bc* is carried over in the manner shown. The procedure consists in subdividing the side of the block *BC* into parts corresponding to *l*, *m*, *n*, *o*, *p*, *q* on the cross-section. Although this procedure ignores the principle that in perspective equal distances become successively smaller in the distance, nevertheless it is an eminently practicable method. In case it is necessary or desir-

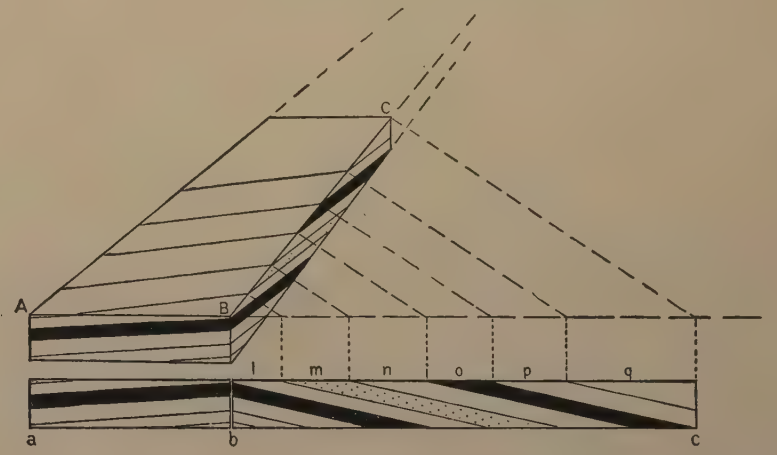


FIG. 15.—Block drawing to show how the geological cross-sections *ab* and *bc* may be transferred to the faces *AB* and *BC* of the perspective block.

able to make allowance for the differences due to perspective, slight changes may readily be made in the dimensions determined in the manner just indicated. On top of the block, then, the geological boundaries may readily be drawn in.

Horizontal beds drawn in cross-section on the side of the block should converge toward the vanishing point, as in Fig. 16, *X*. Short lines forming the symbol for a shale

formation are treated similarly. If horizontal beds are not drawn so as to converge toward the vanishing point, they do not appear to be horizontal. Thus, in Fig. 16, *Y*, the lines separating the different beds shown as horizontal in the true cross-section, *bc*, are drawn parallel to each other

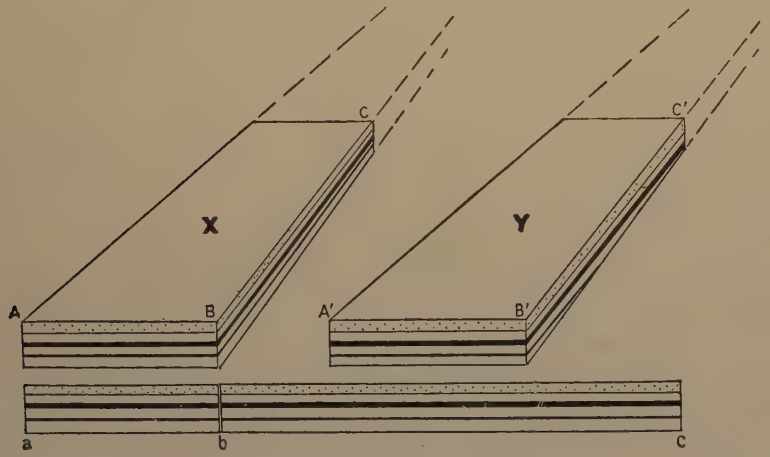


FIG. 16.—Two blocks to illustrate method of drawing geological cross-sections of horizontal rocks on the sides of the block. The short section *ab* is transferred without distortion to *AB* on block *X*; the section *bc* to the side *BC* of block *X*, by allowing the lines to converge toward the vanishing point. In block *Y* the lines of the section on the side *B'C'* do not converge toward the vanishing point and the formations therefore do not seem to lie horizontally. *X* is correctly drawn, *Y* is incorrectly drawn.

and to the top of the block, with the result that some of the beds seem to dip away from the observer.

Beds of limestone are represented in the true cross-section as though made up like a brick wall. When these are drawn in perspective at the side of the block (Fig. 17, *X*), the vertical lines should be drawn vertical, following the universal rule of perspective that all lines which are vertical in the object always appear vertical in the drawing. The correct manner is shown in Fig. 17, *X*. If these short lines are drawn perpendicular to the bedding planes in the perspective view an effect like section *B'C'* in Fig. 17, *Y*, is produced, again giving the feeling that the beds are not horizontal.

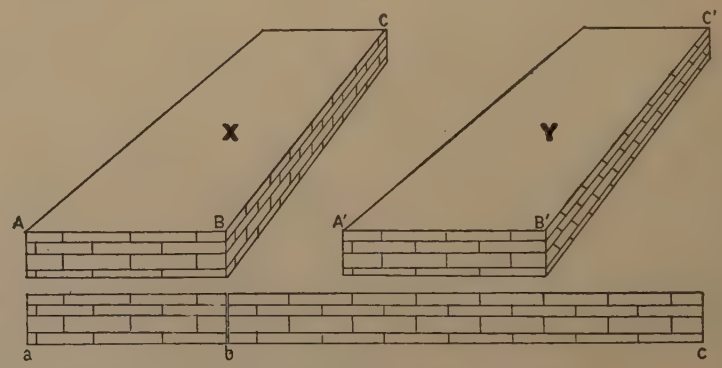


FIG. 17.—Correct method (block *X*) and incorrect method (block *Y*) of representing horizontal limestone beds on the side of the block. It is essential that the partitions between the limestone bricks be drawn vertical.

Folded beds in cross-section must be carefully drawn, to preserve their correct attitude in perspective. Thus, take a series of symmetrical folds having their axial planes vertical, as in the true section *bc*, Fig. 18. To draw these in perspective, the position of the axial planes *l*, *m*, *n*, *o*, *p*, *q*, *r* should first be indicated by similar vertical lines on the perspective block and the folds then drawn in as shown in Fig. 18, *X*. When this is done, the dip of the strata on each side of the axial plane appears to be equal and the desired effect is produced. This is true even though dis-

tances like NF in the perspective view, are much less than NE although these two distances are the same in the true cross-section. An incorrect rendering is shown in Fig. 18, Y, where the folds of the true cross-section are transferred to the perspective drawing without materially altering their form, but instead of appearing symmetrical they appear strongly overturned.

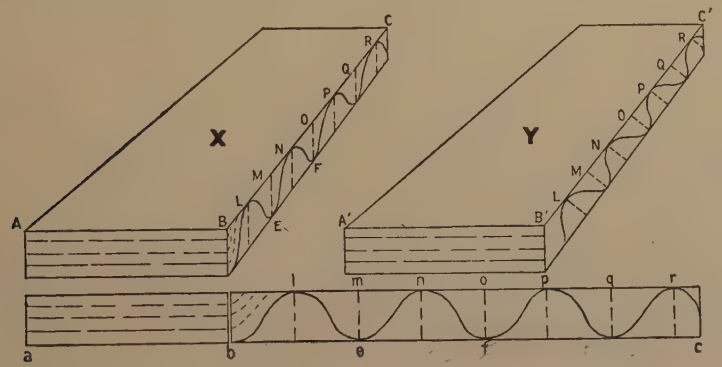


FIG. 18.—Correct method (block X) and incorrect method (block Y) of representing symmetrical folds on the side of the block. It is essential that the axial planes of the folds be kept vertical.

Unsymmetrical folds or overturned folds of any kind may readily be transferred by indicating first the position of the axial plane. Thus, in Fig. 19, X, the side of the block BC represents the perspective appearance of the overturned folds shown in the geological cross-section bc. The axial planes l, m, n, o, p, q, r have been transferred from the undistorted section bc to the distorted one, BC, after the manner of Fig. 15, thus facilitating the representation of the folds. Fig. 19, Y, shows another convenient symbol which may be used to represent schists or very intimately folded beds. Note that in the side face, $B'C'$, the axial planes maintain a vertical position in accordance with the section $b'c'$.

14. Representing geological structure on the surface of the block.—Geological structures may be represented upon the plane surface of the block without suggesting any topography. This renders an important service in showing the relation between surface geology and underground cross-sections, as shown in Fig. 20. Where faulting is involved, this method of presentation may help materially in clarifying the situation. The representation of structural subjects, however, is usually better accomplished by some form of isometric drawing, as explained under Section 110.

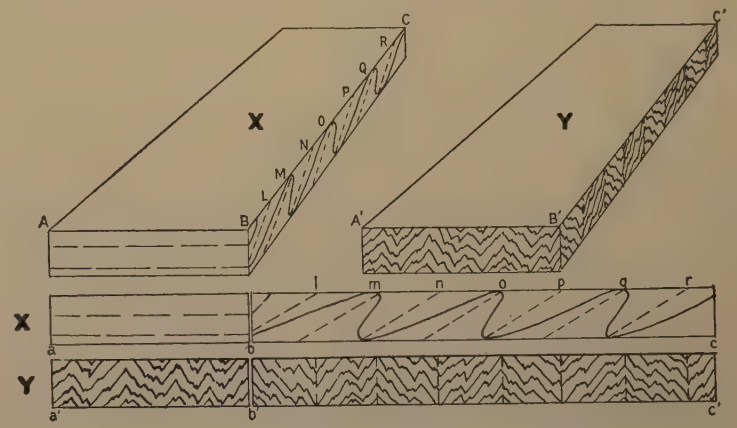


FIG. 19.—In block X the face BC indicates the correct method of representing the geological section of overturned folds shown below in the cross-section bc. Block Y utilizes another symbol for close folding. In these cases it is essential that guide lines such as the axial planes l, m, n, o, p, q, r, be transferred properly to the face of the block, following the method of Fig. 15.

Isometric perspective permits all lines that are parallel in the object to be drawn parallel, and it allows measurements to be made to scale throughout the drawing.

15. Trimming the block by eliminating useless corners.—It was noted in Section 12 that the blocks farthest to the right and farthest to the left, in a system of blocks drawn in one-point perspective, are in general the most useful, because they present the largest cross-sections of the side faces to the observer. For purposes of publication, however, such blocks are very wasteful of space, on account of the long acute corners at the right and left, Fig. 21, *A*. These corners may be eliminated as shown in Fig. 21, *B*, and the waste space materially reduced. All four corners may be eliminated if desired. One method of doing so is shown in Fig. 22. The surface of the block is divided into nine equivalent parts, as in Fig. 22, *A*. This is done by dividing the front of the block into three parts and extending lines therefrom toward the vanishing point. In a similar manner the block is divided from front to back into three parts by horizontal lines. Diagonals are then drawn across the corner sections, and the edges of the block are completed as shown in Fig. 22, *B*. This may be done with a block of any shape and usually results in a more compact drawing without any material loss of desirable information.

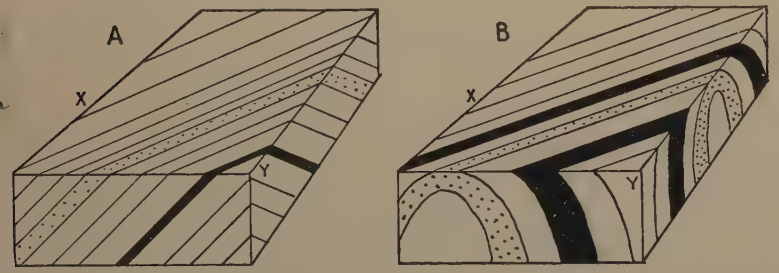


FIG. 20.—Blocks showing structural sections along the sides and formational outcrops on the top of the block.

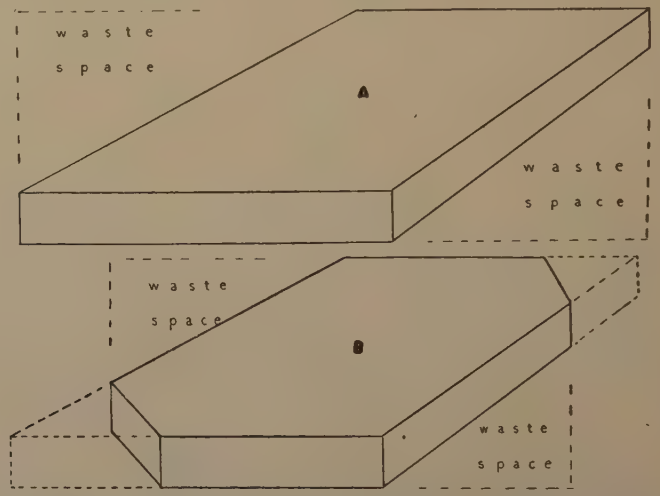


FIG. 21.—Block *A*, drawn in one-point perspective, illustrates what a large part of the printed page is taken by the pointed corners at the right and left and the waste space that results. In block *B* the corners have been cut off to save room and the waste space has been reduced to one-half. Very little of the block is thus lost, but it is made much more compact.

16. Sections cut out of a block.—A section may be cut out of a block along any line, by proceeding as follows: In block *A*, Fig. 23, it is desired to show structural cross-sections along the lines *ST*, and *X Y*. This has been done in block *B*. At *S* and *T* (block *B*, Fig. 23), drop vertical lines until they meet the bottom of the block at *P* and *R*. Join *P* and *R*. The face *STPR* represents the cross-sec-

tion. Then, on the top face of the block, in front of the cross-section but far enough away from it to leave the entire surface of cross-section $STPR$ open to view, draw the line JK parallel to PR. At K drop a vertical line to the bottom of the block. Erase the unnecessary lines JS and TK, and

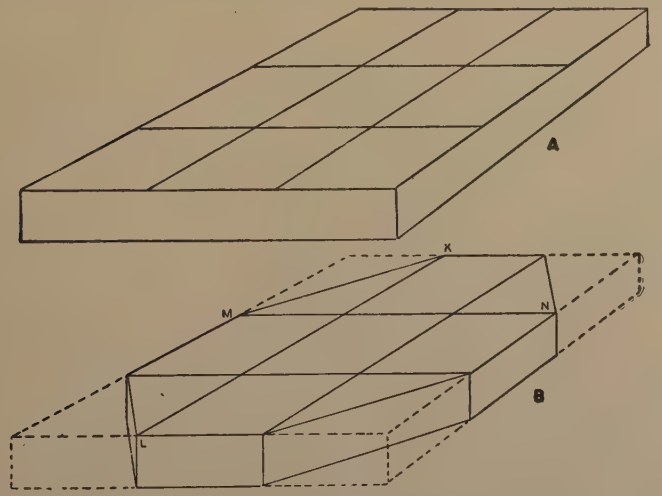


FIG. 22.—Block A, a block in one-point perspective, divided into nine parts, corresponding to the net of meridians and parallels on the U. S. topographic maps. Block B, the same with each corner eliminated in order to gain compactness, to introduce new cross-sections, or to provide variety in presentation.

other construction lines. A similar section has been put through at XY.

17. Pulling a block apart along a section.—The drawing of a cross-section through the middle of a block, in the manner just described, removes a portion of the block. It is like cutting a trench through the block and throwing away the piece. This necessitates the elimination of a considerable strip of territory. It is to be avoided, if possible, because a cross-section is usually put through at some vitally interesting place where it is highly desirable to retain all the adjacent topography. To avoid losing any part of the block, one may cut it through, as it were,

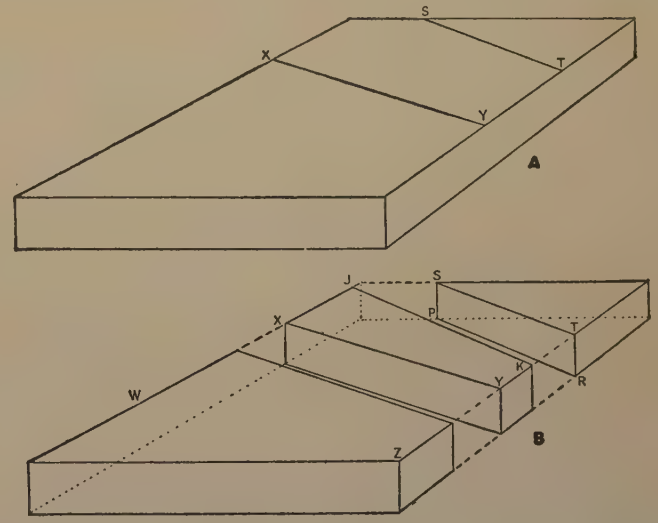


FIG. 23.—Block A is an ordinary block with two lines indicated, ST and XY, along which it is desired to show cross-sections. In block B this is done by removing sections of the block to permit a view of the vertical planes passed through these lines.

and pull one part away from the other. Thus, in Fig. 24, the block used in Fig. 23 has been pulled apart so as to expose the section ST. This pulling apart may be done most effectively by imagining the smaller piece to be moved parallel to one of the faces of the block. Thus, in Fig. 24, A, the small corner is pulled sidewise in the direction EG, and in Fig. 24, B, the small corner is pushed back along the

line *FG*. Either of these methods is satisfactory and is preferable to moving the small triangle out at some oblique angle, because its relation to the rest of the block would, in the latter case, be less evident. In general, it may be said that the method adopted in Fig. 24, *B*, is preferable to that

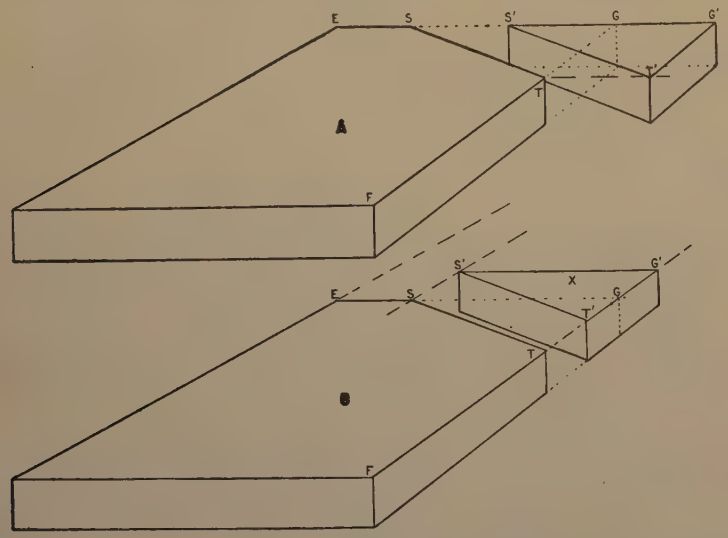


FIG. 24.—Methods of separating a block to show cross-section along the line *ST*. Block *B* is to be preferred to block *A* because it preserves a continuous cross-section along *FG'* whereas block *A* has an offset at *T*. Neither of these methods loses any of the surface of the block such as occurs when sections are cut out, as in Fig. 23.

used in Fig. 24, *A*, because the former preserves a continuous geological cross-section along *FG* whereas the latter produces an offset at *T*. If the lower left-hand corner of the block is to be shifted, then the horizontal shifting is more desirable, as in Fig. 25, *A*, because this preserves a continuity along *FH* whereas if the piece were shifted forward the continuity would be interrupted as at *J*, Fig. 25, *B*. Either method, however, may be used with advantage, depending upon circumstances.

18. Drawing topographic quadrangles in one-point perspective. The representation of a single topographic

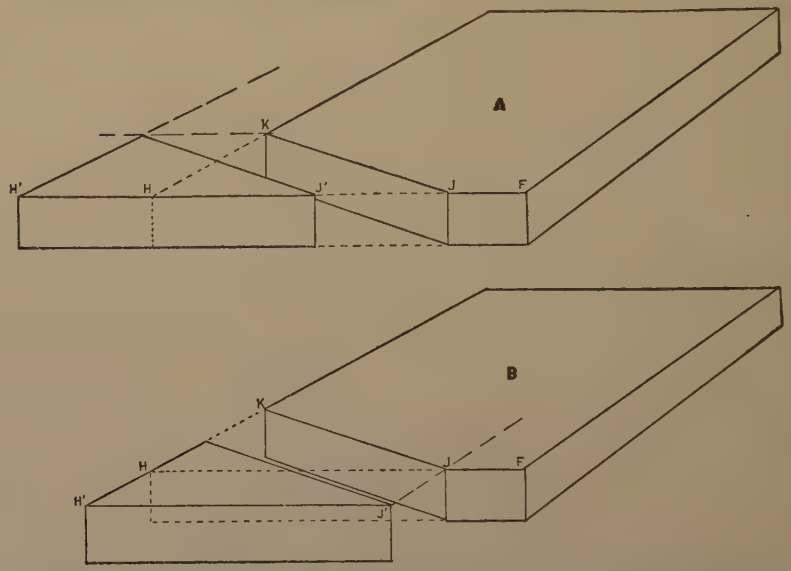


FIG. 25.—Methods of separating a block to show cross-section along the line *JK*. Block *A* is to be preferred to block *B* in that it preserves a section in one plane along the front of the block without any offset such as occurs at *J* in block *B*. However, in block *A* the topography on the surface would be thrown more out of position than in block *B*.

map, or a group of maps, as a single block is often highly desirable when the structure and the topography of the maps in question are to be explained. It necessitates first the drawing of the block with a network of meridians and parallels, to facilitate the putting in of the details. The

block and network may be drawn with definite regard for the principles of perspective in every detail and all dimensions properly measured, but this entails unnecessary expense of time and little is to be gained by such accuracy. Instead, a block representing a single topographic map may be drawn, as in Fig. 26, in which the apparent length from front to back is greater than the width of the block. Most topographic maps of the U. S. Geological Survey are divided into nine smaller rectangles by meridians and parallels.

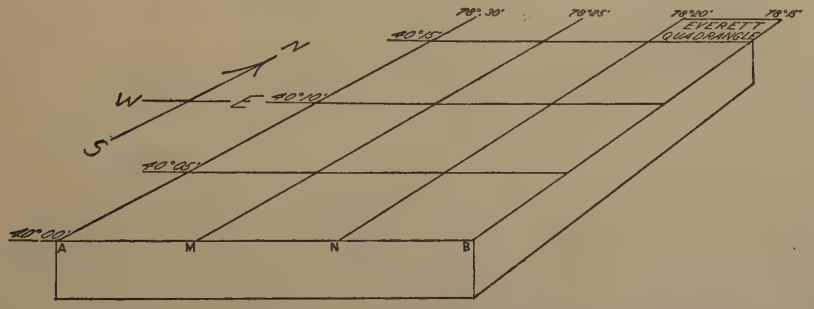


FIG. 26.—Outline of block for representation of topographic quadrangle in one-point perspective. The network of meridians and parallels is drawn to serve as a guide in locating the topographic forms.

These are at 5-minute intervals when the scale is 1: 62,500, at 10-minute intervals when the scale is 1: 125,000, and at 20-minute intervals when the scale is 1: 250,000. This division is accomplished on the block, as shown in Fig. 26, by dividing the line AB into three equal parts and drawing the meridian lines from M and N toward the vanishing point. The parallels are then drawn as horizontal lines, the spaces between them being equal, or successively shorter toward the rear of the block.

The position shown in Fig. 26 is probably the most natural one in which to place the block representing the topographic map, because north is away from the observer. Other positions may be selected, however, as in Fig. 27, if, for instance, it is desired to show the structural section at the west side of the block. In Fig. 27, if it were desirable to show the north end face of the block instead of the southern end for use as a cross-section, the vanishing point should be selected to the left instead of to the right of the block.

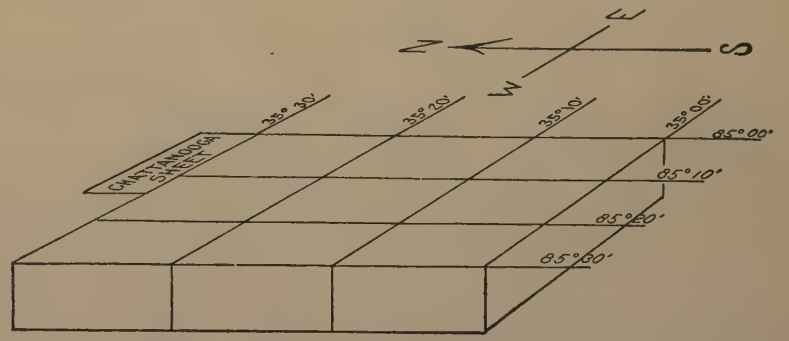


FIG. 27.—Outline of block for representation of topographic quadrangle in one-point perspective. The block is placed so that the western side faces the observer in order that the structural cross-section on that side may be visible.

The representation of a group of maps as a block is done in a similar manner (Fig. 28) or the blocks may be separated along their edges to permit of structural cross-sections as in Fig. 29; or corners and parts of the blocks may be removed entirely or pulled partly away (Fig. 30).

19. Drawing large areas in one-point perspective.—Maps of large areas, such as the British Isles, may be changed into block form by observing the above methods. The

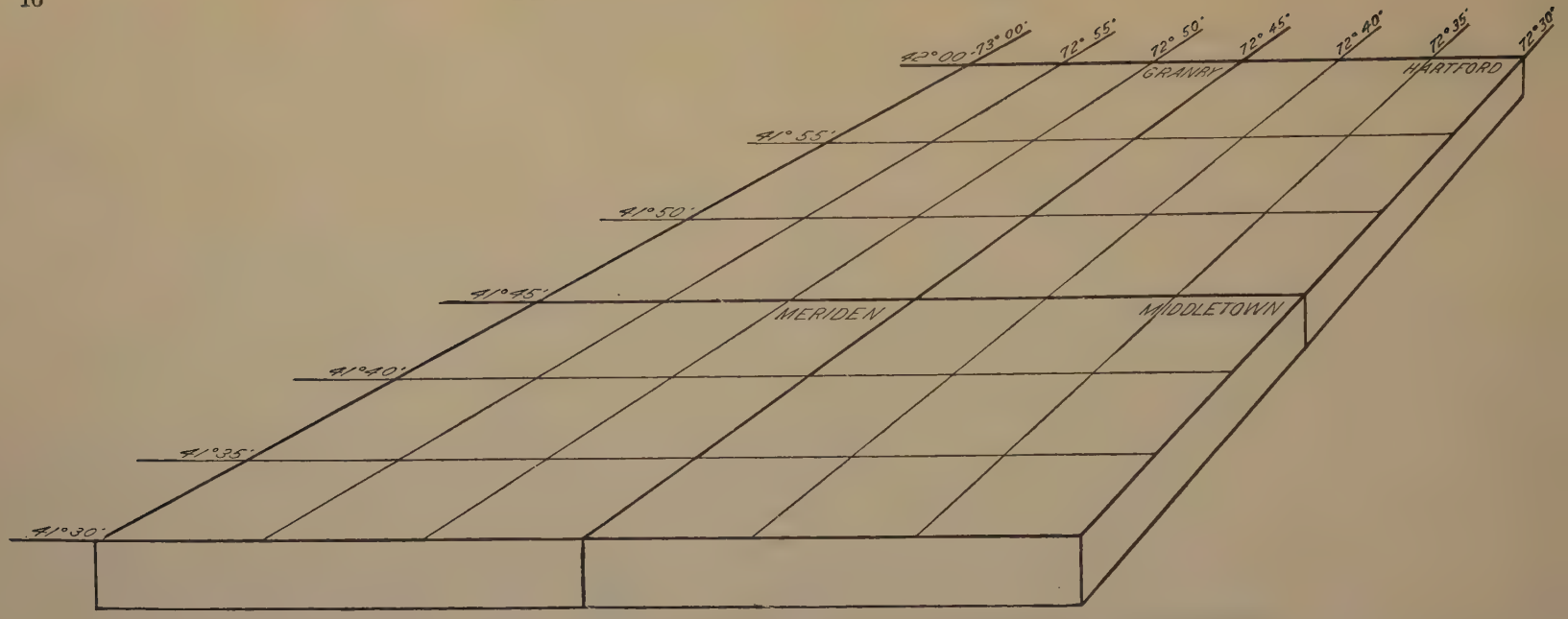


FIG. 28.—Outline of block for representation of group of topographic quadrangles in one-point perspective.

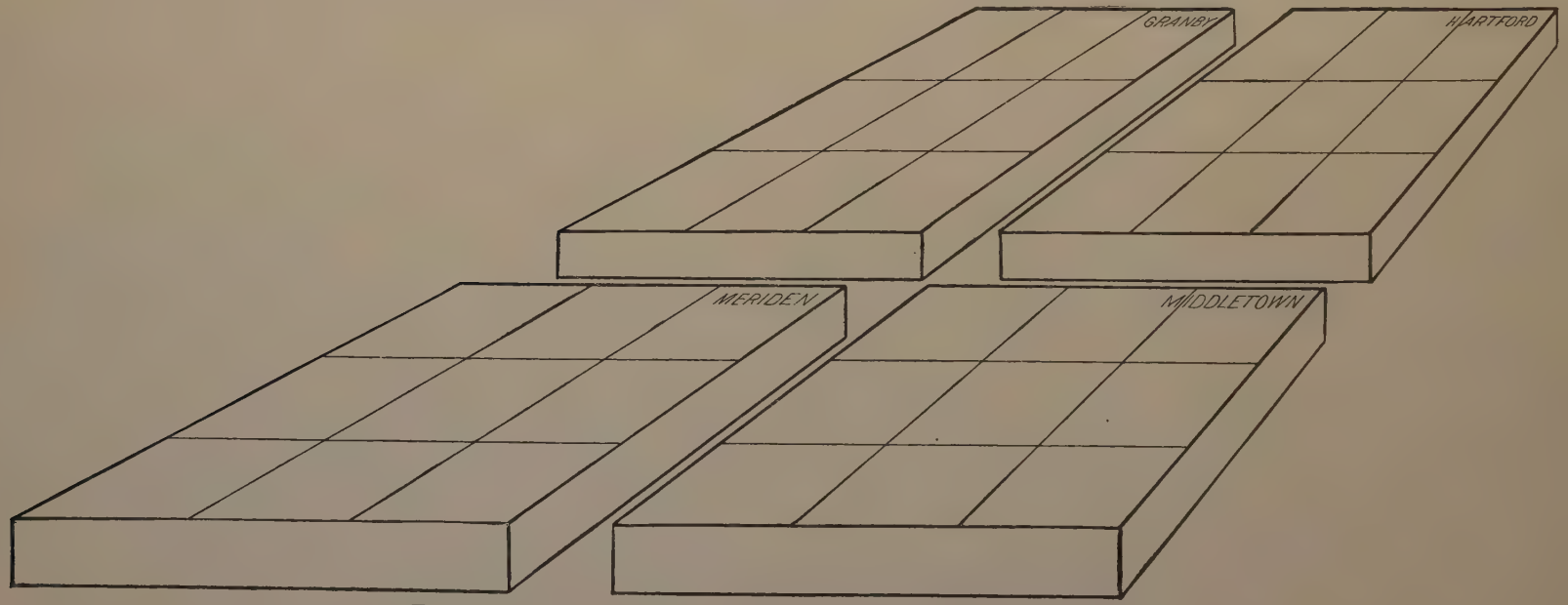


FIG. 29.—The same as Fig. 28 with the blocks separated from each other.

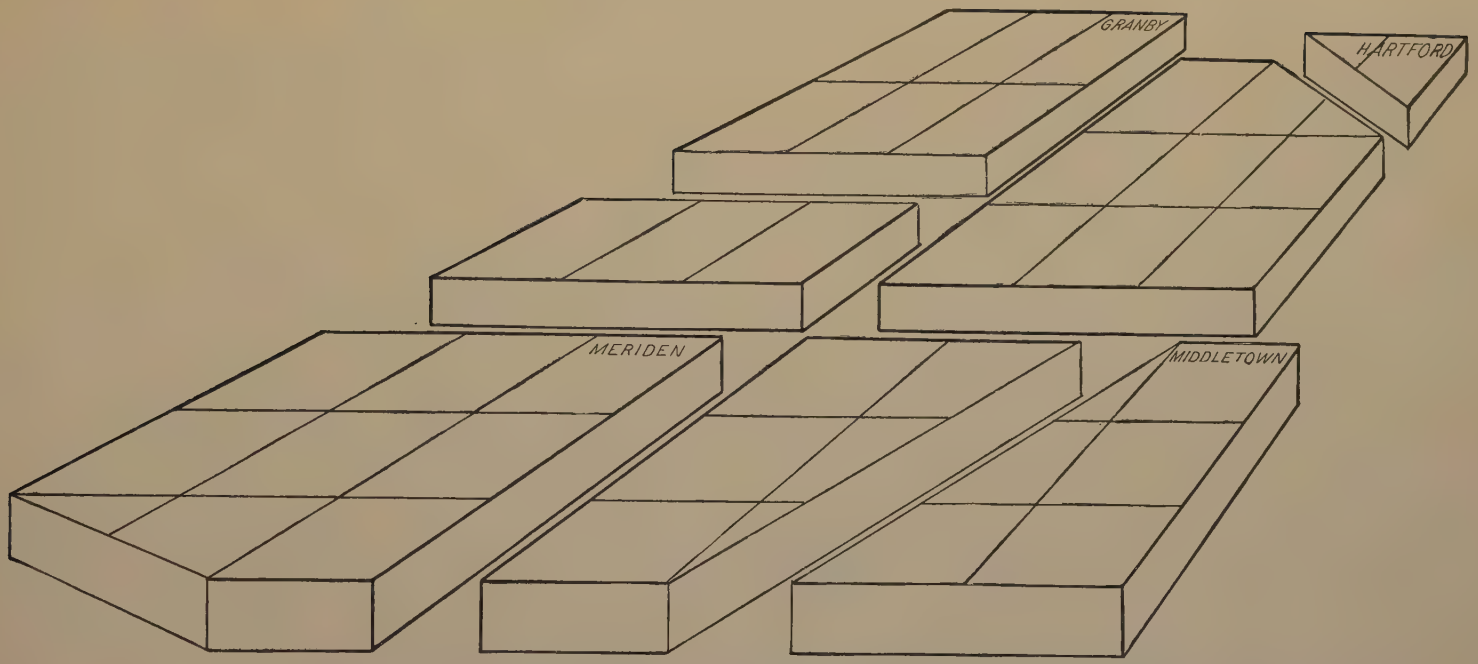


FIG. 30.—The same as Fig. 29 with the introduction of cross-sections and other changes.

net on the top plane of the block may represent the meridians and parallels, as in Fig. 31, or any other net may be used which will facilitate transferring the map to the block. A large block of this type may then be cut apart in order to show structural sections at critical places.

A strong criticism may be made against blocks of this type. The distortion due to perspective is very readily noted in areas like the one represented in Fig. 31, which have acquired a certain familiarity of form to most people in their work with maps. It is therefore suggested that the map itself can frequently be used as a base upon which the topography may be drawn. This is further discussed under Section 129.

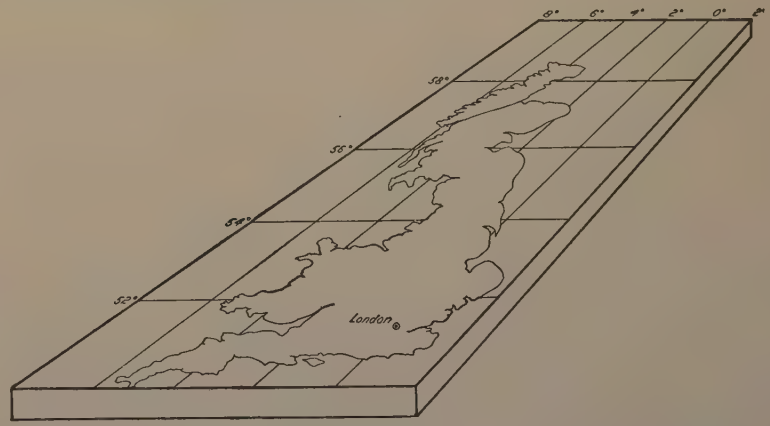


FIG. 31.—Great Britain represented on a block in one-point perspective.

20. Simple geometrical forms in one-point perspective.—Thus far, attention has been directed to the representation of the block upon which the topographic forms are to be placed. The representation of these topographic forms must next be considered. This can best be accomplished by analyzing them and thinking of them as made up of simple geometrical lines and solids, which are more readily drawn in perspective than complicated landscapes having apparently no particular shape which can be analyzed. Much of this book will be devoted to this analysis of land forms and to suggesting devices which may be found useful in drawing topographic details. In Fig. 32, some simple geometrical blocks are represented in one-point perspective, in order to show that such forms are easily drawn, and that the principles of perspective, such as the use of a vanishing point, can be applied to the drawing of pyramids, cones, triangular blocks, and cylinders, as well as to the rectangular blocks already discussed.

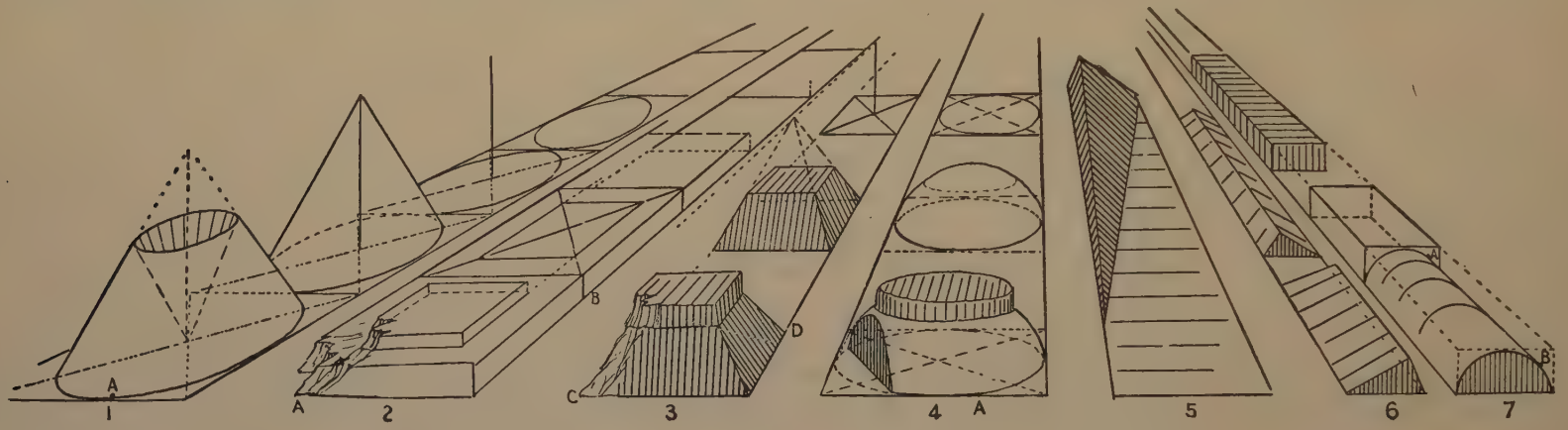


FIG. 32.—Series of geometrical blocks drawn in one-point perspective. Series 1 suggests the successive operations in the drawing of a cone. First, in the back of the drawing, lay off a rectangular base, inscribe a circle, erect a perpendicular at the center to any height desired, then draw lines from the apex of the cone tangent to the circle at its base; finally truncate the top of the cone and introduce an inverted cone to simulate possibly the crater of a cinder cone. Series 2 suggests that a number of rectangular blocks may be placed on top of each other, later to have the corners trimmed off in order to develop a mesa or plateau. Series 3 illustrates the several steps in drawing a pyramid, truncating it, and placing on top a rectangular block. Series 4 shows a sphere which may be truncated and surmounted with a disk, or cut in half as if it were a hill partly eaten away by waves along the coast. No. 5 shows a wedge-shaped block which might simulate the tapering splinter-like end of a block mountain. No. 6 shows two triangular blocks, the farther one having slopes so gentle that both the back and front are visible, the nearer one presenting but one slope to the observer. No. 7 shows that a cylinder may be derived from a rectangular block. Note that the line AB is not along the crest of the cylinder, nor is it at the bottom; it is a line tangent to the two circles representing the ends of the cylinder.

21. Slope lines and shading on geometrical blocks.—Slope lines are drawn on the sides or the top of solid forms,

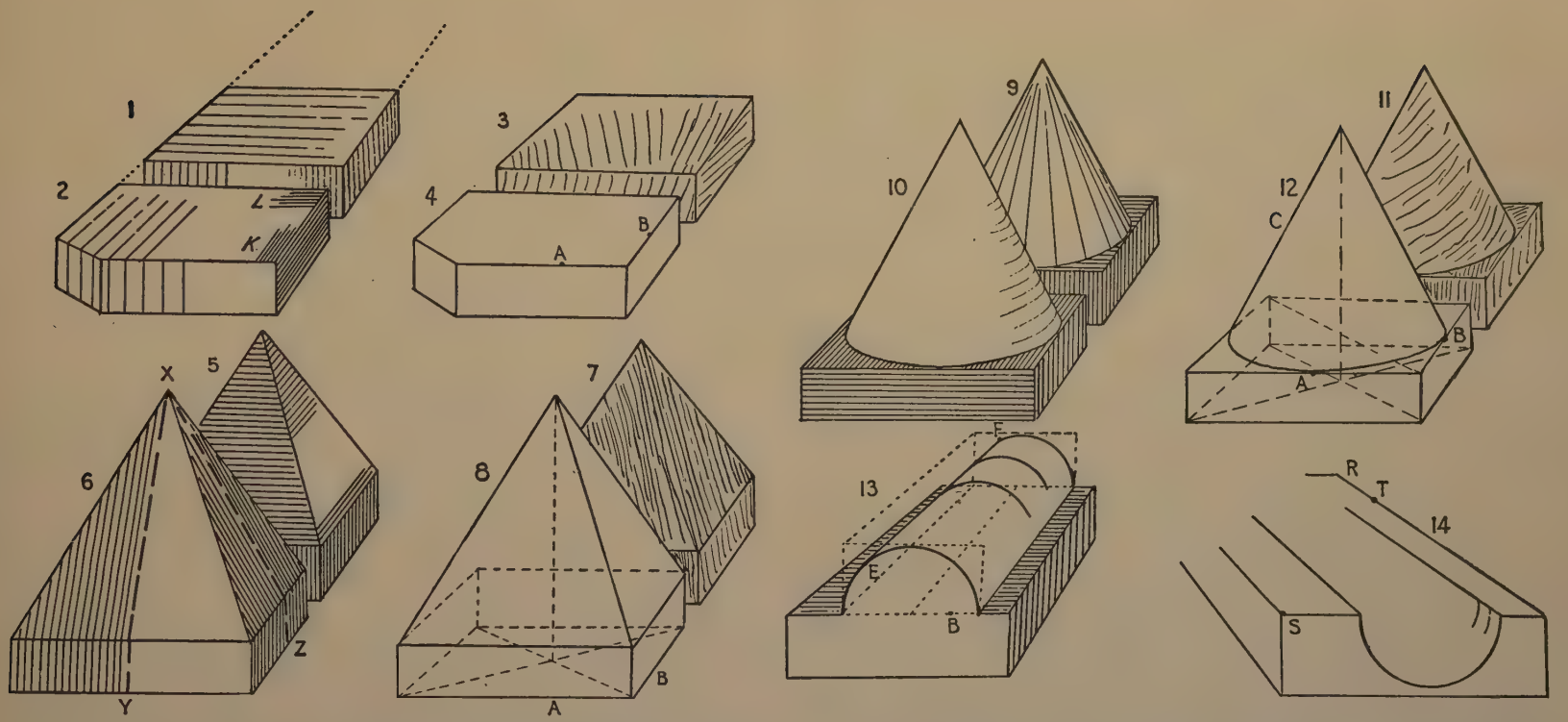


FIG. 33.—A series of blocks to illustrate methods of shading or of drawing slope lines to emphasize the different planes. Note that blocks 1 and 2 have been shaded properly, block 3 improperly. In block 1 the vertical sides of the block have been shaded with vertical lines drawn either free-hand or with a ruler. In block 2 horizontal shading has been used at one end. Such lines should, of course, converge toward the vanishing point. The shading on top of the block may converge toward the vanishing point as on the left side of block 2, or may be made up of horizontal lines as on top of block 1. The shading on top, however, should not run in the same direction as the shading on the side, as at *K*, but rather as at *L*, in order to accentuate the different planes. If the shading on all the vertical sides of the block is made up of vertical lines as in block 1, it is well to draw the corners of the block with a heavier line, and also to space the strokes on the retreating side of the block nearer together than on the front of the block. In block 3 several of the principles mentioned have been violated. Study of the four pyramids shows that 5 and 6 are correctly shaded. No. 7 is improperly done. No. 8 has been left blank for the student to work on. On block 5 horizontal lines have been used on the sloping sides of the pyramid. On block 6 slope lines are used. The direction of these lines is determined by drawing lines *XZ* and *XY* from the apex to the middle points along the base. The slope lines are made parallel to these lines. In cones 9 and 10 suitable methods have been used, slope lines in No. 9, horizontal lines in No. 10 which appear as ellipses in perspective. Block 11 is poorly drawn. In block 13 the slope lines on the cylinder are circles which are tangent to the line *EF*.

to aid the reader in distinguishing the different planes which bound the solid, and to help him to appreciate quickly the attitude or slope of each plane. Two principles are to be followed in drawing such lines. First, slope lines should run directly down the slope, not across. An exception to this is made in the case of shading consisting of horizontal lines crossing the plane, but these lines are strictly not slope lines. A second principle requires that all slope lines on a given plane be parallel with each other; that is, in perspective they all converge toward the same vanishing point. Fig. 33 and the accompanying description should now be examined.

EXERCISES

Based upon the Illustrations in Chapter II

Note.—The student should provide himself with a medium pencil, about a 2H, which is easily erased; a soft eraser, such as artgum; a knife to keep the pencil sharp; a sandpaper pad for pointing up the pencil; carbon paper; sheets of good typewriting paper, or drawing paper, and some tracing paper. Cheap, thin typewriting paper will be very satisfactory as a substitute for tracing paper. A small, inexpensive drawing board, about 12 by 18 inches or even smaller; a small T-square; a triangle; a ruler; thumb tacks and pins, will be needed from time to time. For finished work on drawings to be published, there will also be needed penholder and medium to small sharp-pointed pens but not necessarily crowquill pens, black India ink, penwiper, blotter, and ruling pen, which should be kept very clean and handled carefully. Some harder pencils may also be required, in order that drawings may be completed and nicely penciled in before inking.

Exercise 1. Trace the outline of block *A* in Fig. 6, and then modify it by shortening the back line until it resembles block *B*. Experiment until you find out how much shorter the back line must be to make the block look well.

Exercise 2. On Fig. 7, mark off on the line *AB* of each block, the length of *CD* of the same block, in order to show the relative length of these lines.

Exercise 3. Trace part of Fig. 10 and draw additional blocks on all sides, to the left, right, front, and back of all the lettered blocks; that is, add twenty blocks to the drawing.

Exercise 4. On Fig. 13, complete several other blocks back of blocks *A*, *B*, and *C*. Label each of the blocks in Fig. 13 with the words "top surface," "front face," and "side face." Can a block in one-point perspective show two side faces?

Exercise 5. On blocks *A* and *B* in Fig. 14, draw cross-sections of horizontal bedding similar to block *X* in Fig.16.

Exercise 6. On block *X* in Fig. 16, introduce the limestone symbol below the sandstone layer represented.

Exercise 7. On block *X* in Fig. 16, draw diagonal cross-section from *A* to *C*, thus cutting the block in half. Represent the structure on this cross-section.

Exercise 8. On block *X* in Fig. 17, draw diagonal cross-section from *A* to *C*, thus cutting the block in half. Represent the limestone structure on this cross-section.

Exercise 9. On block *X*, Fig. 18, draw a cross-section from *A* to *C* and show the structure. The folds are symmetrical and without any pitch.

Exercise 10. On block *X*, Fig. 19, draw diagonal cross-section from *A* to *C*, thus cutting the block in half. Represent the structure of the overturned folds on this section.

Exercise 11. On blocks *A* and *B* in Fig. 20, draw diagonal cross-sections *X Y*, thus cutting off the front part of the blocks. Represent the structure on these cross-sections.

Exercise 12. On block A, Fig. 21, cut off the corners, as has been done in block B, but in such a way that a cross-section is visible in the right corner, but not in the left corner.

Exercise 13. On block B, Fig. 22, cut out cross-sections along MN and LK, both on the same drawing.

Exercise 14. On block B, Fig. 23, cut out a cross-section along WZ similar to the other cross-sections in the same block.

Exercise 15. On block A, Fig. 24, cut off a small corner at E and move it to the left in the same way that corner G has been shifted to the right.

Exercise 16. On block B, Fig. 24, cut off a small corner at E and move it back in the same way that corner G has been shifted back.

Exercise 17. On Fig. 26, extend the Everett quadrangle so that it includes 5 minutes more of longitude toward the west and 1 to 2 minutes more of latitude to the north, but cut off the corners so that the engraving requires no more space to the right or left than it now does.

Exercise 18. Increase the area represented in Fig. 28 so that it includes the quadrangle to the west of the Granby sheet.

Exercise 19. On Fig. 29, add one more quadrangle, to the west of the Granby sheet, but detached from it as the others are.

Exercise 20. Detach and move forward the southern third in each of the two halves of the Middletown sheet, Fig. 30, so that an east-west cross-section may be put through along that parallel.

Exercise 21. Take a map from some atlas or other convenient source, and prepare a block similar to Fig. 31 with net and outline of area, as for instance, your home state, France, Australia, or Lake Erie.

Exercise 22. On Fig. 32, cut the nearest cone of block 1 in half, by a vertical plane passed through the point A and the axis of the cone. Complete the drawing by showing the cross-section of the inner inverted cone. Erase the right-hand half of the cone which conceals this vertical cross-section.

Put a vertical plane through AB of block 2; through CD of block 3; and remove the front half of each block.

Cut off, by means of a vertical plane passed through A, a piece from the right side of block 4, in order to show a section like that shown on the left side.

On block 5, draw another wedge-shaped block, but tapering away from, instead of toward, the observer.

Put a horizontal plane just below the top of the two triangular ridges in block 6. Remove the sharp crest and show the flat summit thus produced. Do likewise for block 7.

Exercise 23. On block 4, Fig. 33, cut off the corner along the line AB, and move it far enough to the right to expose the cross-section. Then shade all plane faces on the block.

Exercise 24. On block 8, Fig. 33, cut off the front right corner of the pyramid, by means of a vertical plane passed through the points AB. Throw the corner away and shade all surfaces of the pyramid.

Exercise 25. On block 6, Fig. 33, truncate the pyramid about half way up. Dot in all construction lines, as in block 8.

Exercise 26. On block 12, Fig. 33, cut off part of the cone by a vertical plane passed through the points AB. Do not cut off the corner of the square block. Also truncate the cone by means of a horizontal plane passed through C. Shade all surfaces on both the block and the cone.

Exercise 27. Complete block 14, Fig. 33, and shade all surfaces.

Exercise 28. Complete block 14, Fig. 33, then cut off the front half by a vertical plane passed through ST, and shade all surfaces. In block 14, what line corresponds to line EF of block 13?

CHAPTER III

TWO-POINT PERSPECTIVE

22. Simple rule not always safe.—In one-point perspective, a simple rule advised drawing the sides of the block so that they would taper toward the rear. This is done in two-point perspective also, but a precaution must be observed in doing it.

Two-point perspective is used when the rectangular block stands with its corner toward the observer. The result is that the two sets of lines which are at right angles to each other in the object appear to taper in two directions, one set meeting at the right in one so-called vanishing point upon the horizon, the other set meeting at the left in a second vanishing point, also upon the horizon, as in Fig. 34, *Y*. The precaution to be observed is that the two vanishing points shall be upon the same horizontal line. Note in Fig. 34, *X*, that this has not been done, and that the line connecting the two vanishing points is not horizontal. The resulting block, therefore, does not seem to lie flat upon the page. The whole figure must be turned until the line *AB* becomes horizontal, as in Fig. 34, *Y*.

Because it is difficult to judge the exact position of a vanishing point when drawing a block freehand, it is therefore more than doubly difficult to draw the block when two points have to be kept in mind and when both points have to be upon the same horizontal line. It is consequently more necessary, in adopting two-point perspective, to make use of the required construction lines, whereas these may be dispensed with when the more simple one-point method is followed.

23. Draw the block small, then enlarge it.—Because the two vanishing points must actually be used in constructing the picture of the block in two-point perspective, a very large piece of paper must be used to draw a block out carefully; if an ordinary-sized piece of paper is used the block will be too small for most purposes. The remedy for this is to draw the block small and enlarge it afterward. This gives opportunity to draw experimentally a number of blocks in different positions and afterward select the one that appears most suitable. The one selected may then be enlarged. Imagine, in Fig. 35, *X*, that a number of blocks have been drawn and *ABCD* has been selected as a suitable one for the purpose in mind. *ABCD* is too small, however, and should be three times as large. This enlargement is conveniently made by laying the sheet of paper containing *ABCD* upon another sheet, and pricking through the three corners, *ABC*, with a pin or using any other method of transferring. This gives Fig. 35, *Y*. Then draw *BAK* (Fig. 35, *Z*) so that *BK* equals three times *AB*, and *BCL* so that *BL* equals three times *BC*. In similar manner at *K*

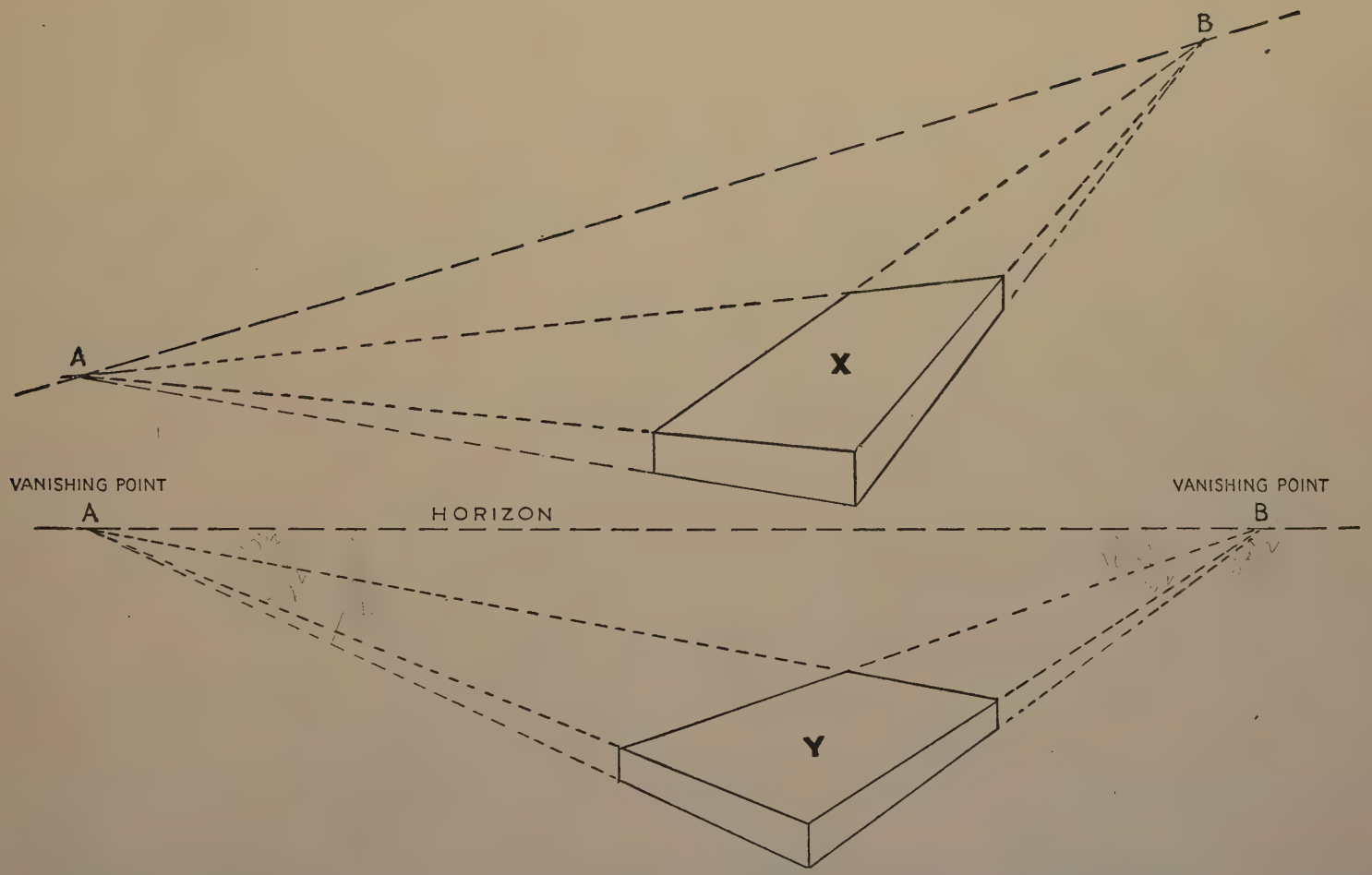
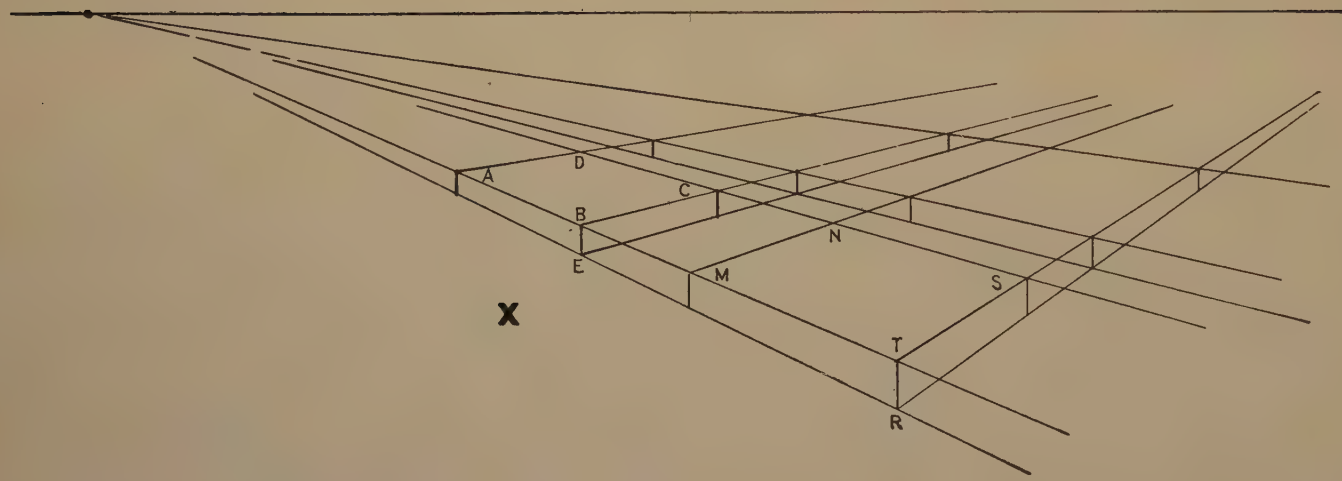
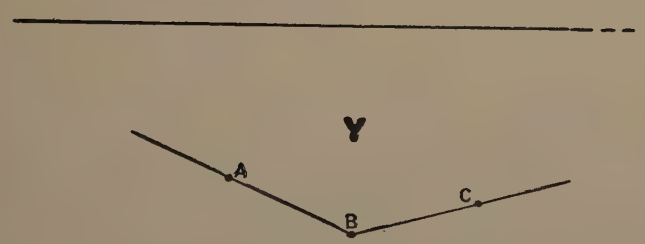


FIG. 34.—Correct method (*Y*) and incorrect method (*X*) of drawing blocks in two-point perspective. The correct method requires that the two vanishing points, *A* and *B*, be on the same horizontal line. In block *X* the line *AB* is not horizontal.





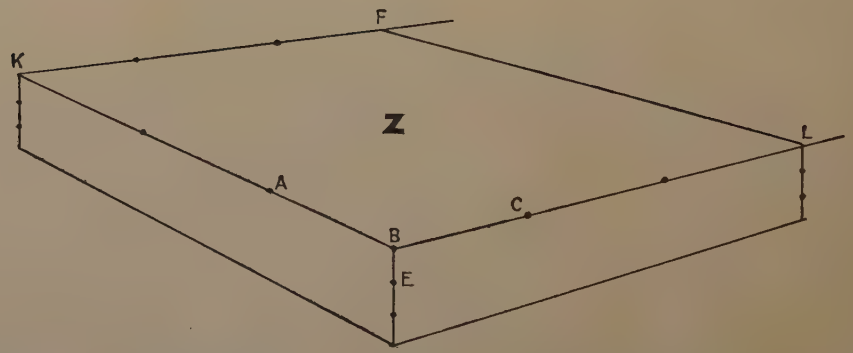


FIG. 35.—Method of enlarging a block. In *X* a number of blocks have been drawn in the two-point perspective system. Block *ABCD* has been selected and in *Z* has been enlarged to three times its original size. *Y* represents the first step in which the angle *ABC* is carried over from the smaller block, the lines *BA* and *BC* then being extended to three times their former length to form the sides of the large block *Z*.

transfer the angle BAD and at L the angle BCD. Complete the block.

A convenient method of transferring angles is shown in Fig. 36. The angle ABD is to be transferred. Take a piece of paper. Place one edge against the line AB as shown. Mark the point C upon the paper where the line BD, extended if necessary, emerges from under the paper. Then lay the same sheet of paper in similar position upon the point of the larger drawing where the angle is to be transferred. Mark C and E upon the paper beneath. Connect BE and BC. This method of transferring is extremely convenient when small drawings prepared on paper are to be reproduced upon the blackboard on a much larger scale.

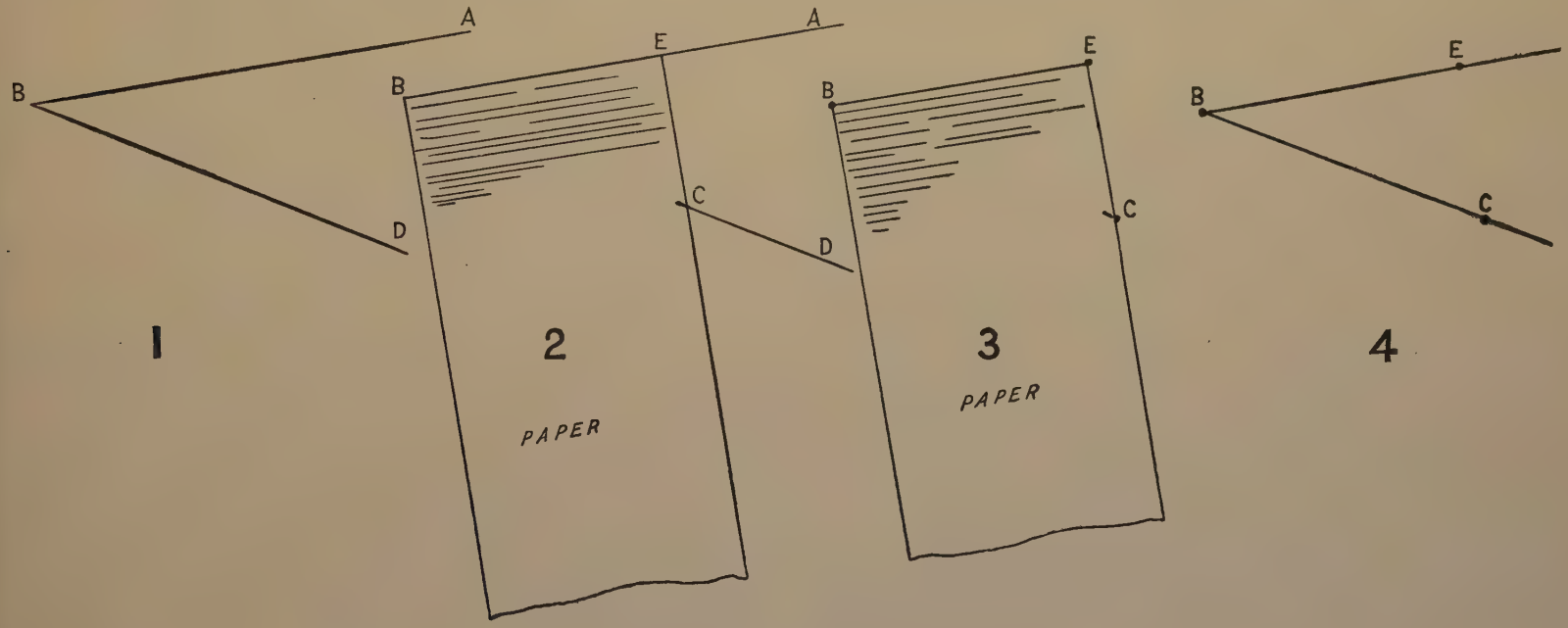


FIG. 36.—Device for transferring angles.

24. Selection of the most suitable block.—In Fig. 37 a series of blocks is presented. It will be noted that only a few of these blocks, lying near the center of the figure, are really satisfactory. Let us criticize the others. The blocks lying in the upper part of the drawing are so much foreshortened that very little surface is represented, and their utility is thus limited. The blocks in the foreground are so near the observer that they have an awkward and

unnatural appearance. Those far to the right and left present, upon one side of the block, a sectional view too small to be of any value. The blocks marked *X* are therefore most satisfactory.

sentation of topographic maps in two-point perspective are done in much the same manner as has been explained for one-point perspective under Sections 16, 17, 18 and 19. The accompanying figures illustrate some specific examples

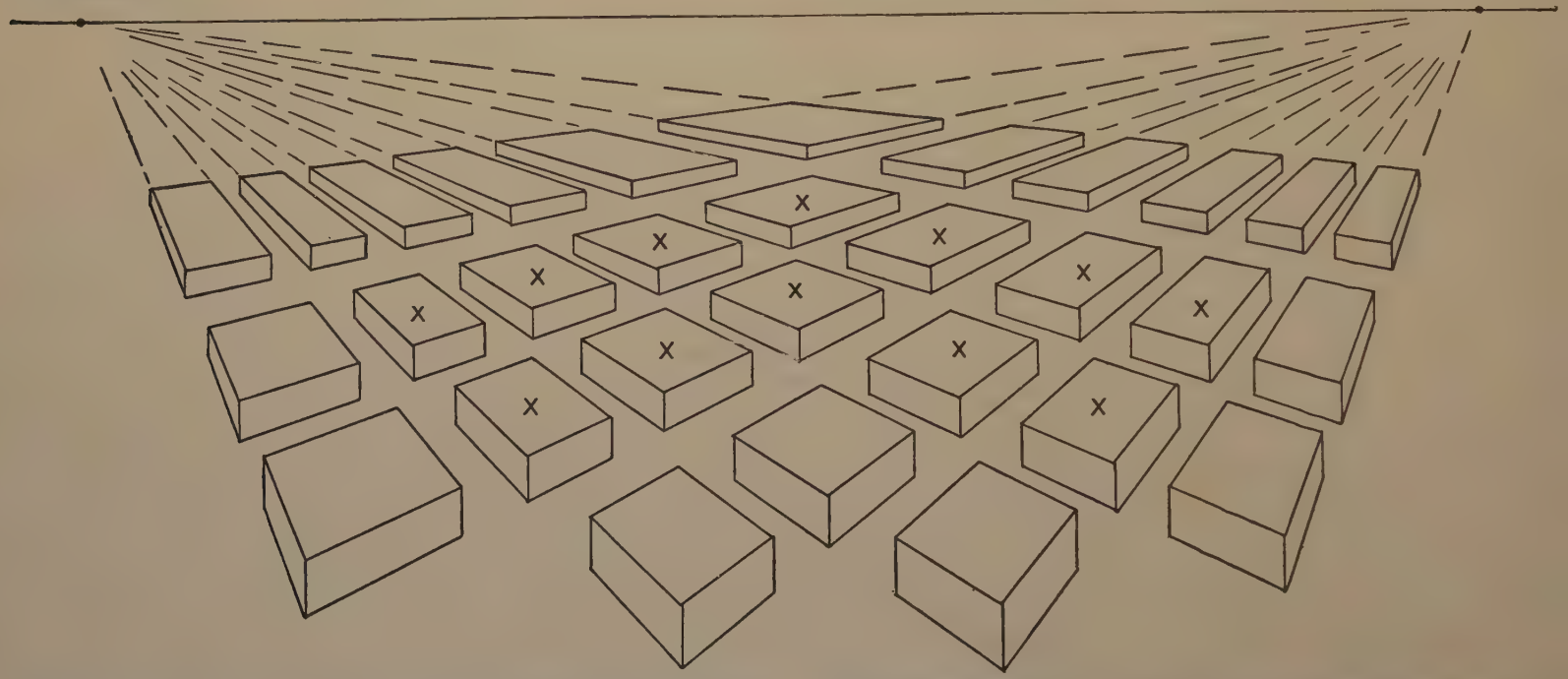


FIG. 37.—Set of blocks drawn in the two-point system. Only the blocks marked *X* near the center are satisfactory. Those near the top are too much foreshortened and present little upper surface. Those far to the right and left show poor cross-sections on one side. Those in front are awkward in appearance.

25. Geological cross-sections and modifications of the block.—The drawing of geological cross-sections, the trimming off of corners, the cutting of sections out of the block, the pulling apart of a block along a section, and the repre-

of the same problems applied to blocks in two-point perspective. Fig. 38 represents four topographic quadrangles in block form ready for the topography and the structural sections. In Fig. 39, covering the same region as Fig. 38,

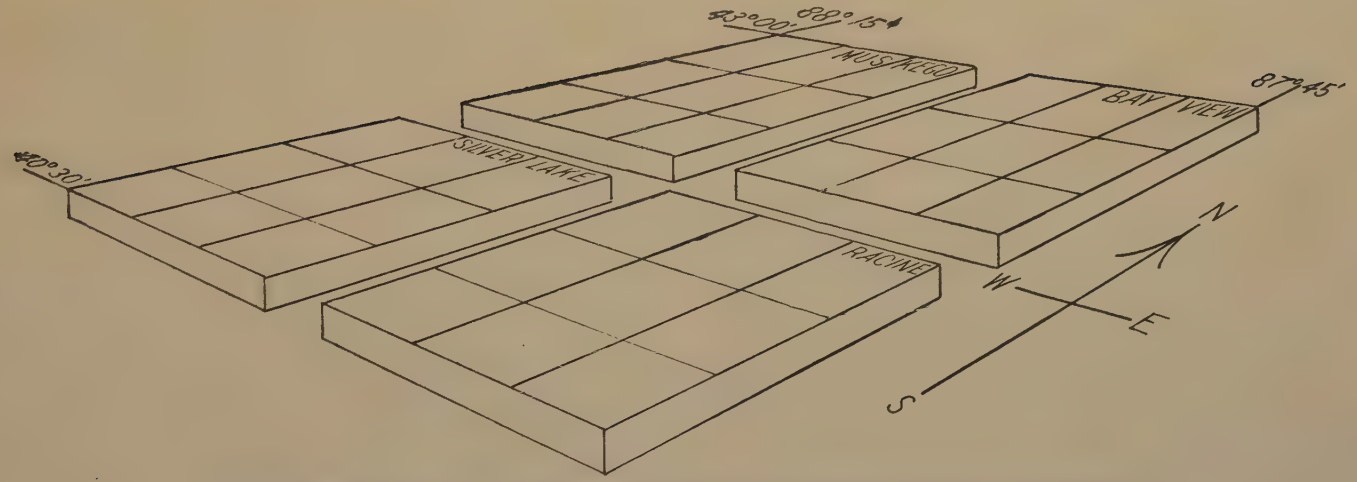


FIG. 38.—Blocks for the representation of topographic maps drawn in two-point perspective

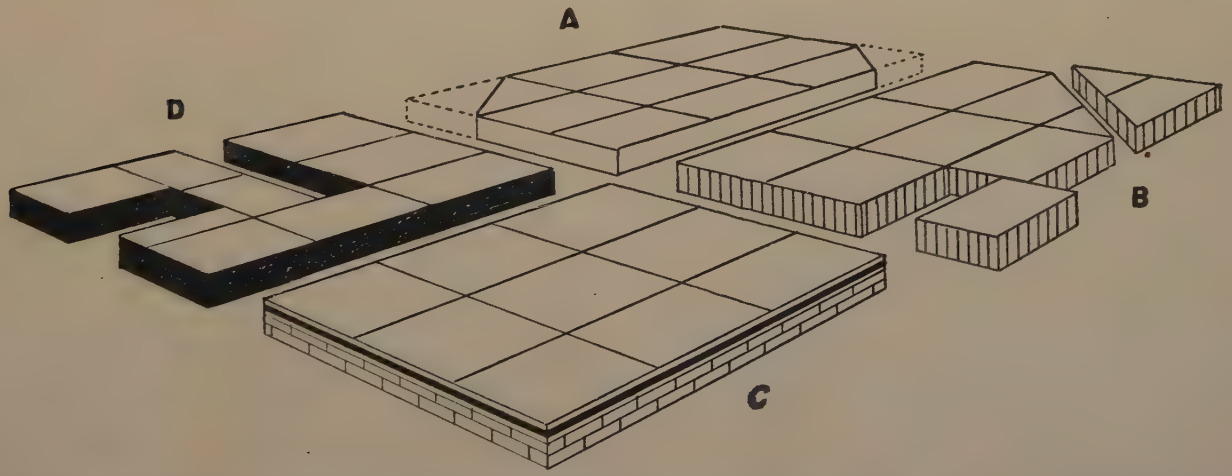


FIG. 39.—Four blocks in two-point perspective altered in various ways to introduce geological sections or to save space by removing corners.

block *A* has been trimmed to a more convenient shape by the elimination of two sharp corners; block *B* has been separated along two lines and the corners have been pulled away from the rest of the block in order to reveal the cross-sections; block *C* shows simple structural sections of horizontal bedding; and *D* represents a block from which two trench-like areas have been removed in order to present vertical sections for the display of structure. In all of these blocks the two vanishing points are well off the paper.

EXERCISES

Based upon the Illustrations in Chapter III

Exercise 1. In Fig. 34, *Y*, draw additional blocks to the right and left of block *Y*, using the construction lines already drawn.

Exercise 2. Determine the position of the two vanishing points for block *Z* in Fig. 35. On block *Z* draw in a smaller block which will be twice the size of *ABCD* instead of three times.

Exercise 3. On block *Z*, Fig. 35, draw lines to the vanishing points from the points *A*, *C*, etc., to divide the block into nine parts, like a topographic map.

Exercise 4. On block *Z*, Fig. 35, cut off a triangular corner at *L* and move it away from the block along the direction *BL*. (See Fig. 24, *B*.)

Exercise 5. On block *Z*, Fig. 35, cut off a triangular corner at *K* and move it away from the block along the direction *BK*.

Exercise 6. On block *Z*, Fig. 35, cut off the front corner along the line *AC*.

Exercise 7. On block *Z*, Fig. 35, remove a block from the front corner, having an area *ABCD* equal to the small block at *X*.

Exercise 8. On Fig. 35, enlarge the block *MNTS* to a size half as large again.

Exercise 9. On Fig. 38, add one more block to the west of the Muskego sheet, but detached from it as the others are.

Exercise 10. On Fig. 39, remove the front rectangle of block *C* and slide it a little to the left in a manner similar to the treatment of the front corner of block *B*. Draw in the geological structure thus exposed.

Exercise 11. In block *C*, Fig. 39, cut out a north-south cross-section along one of the meridians. Show structure thus exposed.

Exercise 12. Draw in two-point perspective a series of flat rectangular blocks piled on top of each other, similar to block 2 in Fig. 32; also a pyramid, a truncated pyramid surmounted by a flat rectangular block, a triangular block showing front and back slopes, a triangular block showing but one slope, and a hemisphere lying on its flat side. Draw in slope lines, or shade each of these forms appropriately according to methods used in Fig. 33.

Exercise 13. (*a*) Draw in two-point perspective a block entirely above the horizon. (*b*) Enlarge it to twice its linear dimensions. (*c*) On the enlarged block show by dotted lines the edges which are invisible. (*d*) Cut off a triangular corner from the enlarged block and shift it along one of the major sets of lines. (*e*) Represent a sectional trench cut through the enlarged block.

CHAPTER IV

PLAINS AND PLATEAUS

26. A simple, unbroken plain crossed by a stream.—We come now to the representation of relief upon the surface of the block. In its unaltered form the block, whether drawn in one-point or in two-point perspective, may be thought of as representing the simplest type of topography, an undissected plain. A plain of this kind may be diversified by the presence of streams meandering across it. The drawing of such meandering streams is readily accomplished by imagining these streams as made up of parts of circles joined to each other. The task then is to draw these circles in perspective. This is facilitated by first drawing on top of the block the perspective view of squares and then inscribing the circles in them. Thus in Fig. 40, *A*, such a network has been laid out and circles have been inscribed. The circles in perspective appear, of course, as ellipses. Parts of these circles have been drawn heavier so as to suggest the continuous course of a stream and its tributaries. Fig. 40, *B*, illustrates the stream thus drawn without the accompanying circles. In Fig. 40, *C*, a freer rendering has been adopted. In this case the stream is drawn by sweeping the pencil to the right and left across the paper, with a slow advance forward. This tends to compact the curves of the stream and produces the foreshortened effect which is desired.

Throughout this whole procedure the idea has been to flatten the original circle and give it a shorter dimension from front to back, that is, to foreshorten it. This causes the river to "lie down" on the plain. If this is not done the stream seems to be arching up and down over the plain like a bent wire, touching its surface only here and there. This incorrect representation is shown in Fig. 40, *D*.

27. Specific example: representation of stream with single line. A very young plain. Fargo quadrangle, N. D.—Minn.—Figure 41 is a simple rendering of the Fargo quadrangle. The streams are small and are cut very little below the level of the plain. No topography is shown on this diagram, as the country is so nearly flat. The streams are represented by single lines, and their irregularities are expressed with considerable freedom. A few of the railroads and one or two towns are also shown. A diagram of this kind used in connection with the map will aid the beginner in visualizing some such description as follows:

The area represented here is a part of the old bed of Lake Agassiz, a shallow lake of great extent which covered much of North Dakota, Minnesota, and Manitoba in glacial time because the Red River, which drained this region, was barricaded at the north by the ice sheet. The Red River and its tributaries now flow on the old lake floor. Because

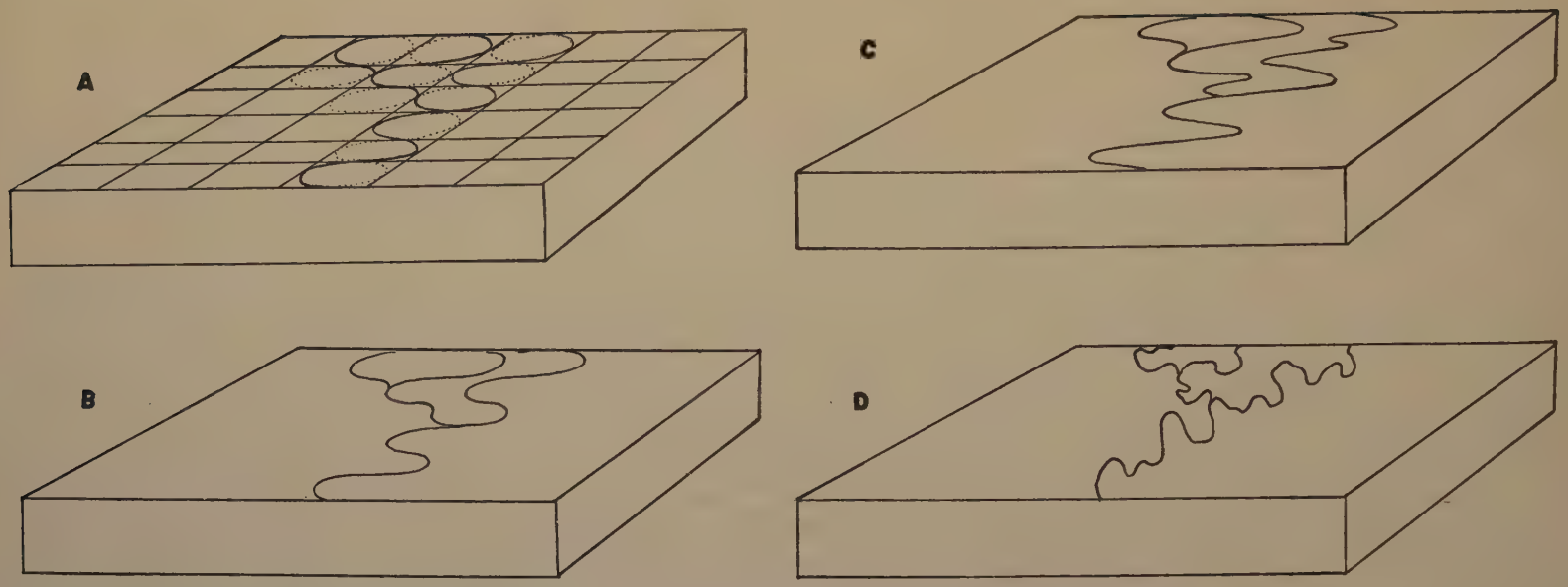


FIG. 40.—The representation of a stream on a flat plain. In block *A* the surface of the plain is laid off in rectangles with inscribed circles which appear as ellipses in perspective. In block *B* parts of different ellipses are joined. In block *C* a freer rendering is effected, thus simulating a simple stream swinging across the plain. In block *D*, which is incorrectly drawn, the foreshortening of the curves was not attained and the stream does not "lie down" on the plain.

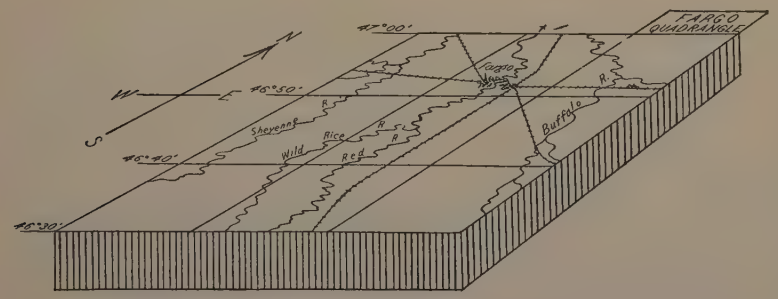


FIG. 41.—Block diagram of Fargo quadrangle, North Dakota. A very young plain.

this floor is so level the rivers have very little gradient and are unable to cut down very rapidly. The streams, although very young, have developed many small meanders. Such streams are technically young, but it is not amiss to say that they also have many of the characteristics of maturity. These streams, at birth, finding themselves upon an almost level plain, assumed a meandering course, and these meanders are now being cut slightly below the level of that plain. The extreme levelness of the country is suggested also by the straight railroads.

28. Representation of wide streams with a double line.—When the stream is represented by means of a double instead of a single line, the two lines should be drawn close together where they run to the right and left across the drawing, that is, transverse to the direction of sight, as at *J* in Fig. 42. Here the distance from bank to bank seems less than at a point *M* where the course of the stream is directed toward the observer. At *J* the width of the stream is foreshortened. The same effect may be noted by viewing Fig. 43 from a low angle with the page held almost level

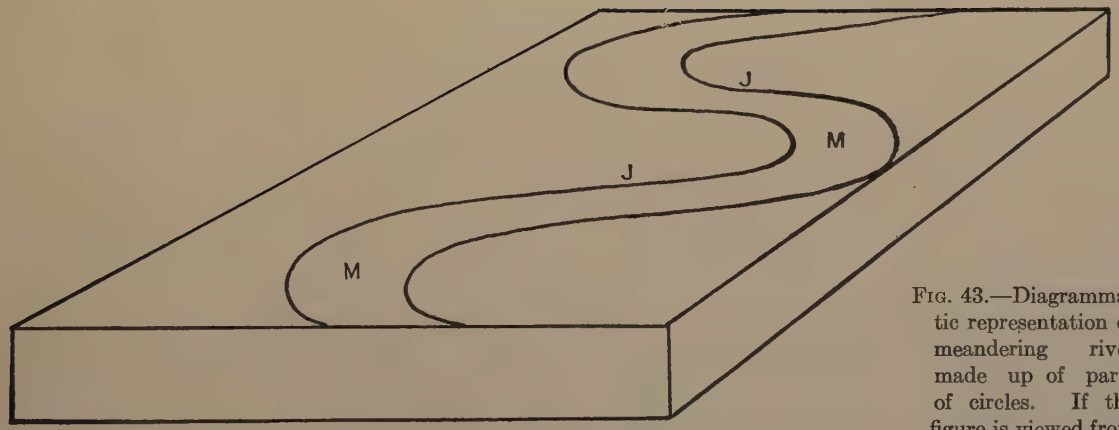


FIG. 42.—Block diagram showing wide river swinging across a flat plain, to illustrate foreshotening at *J*.

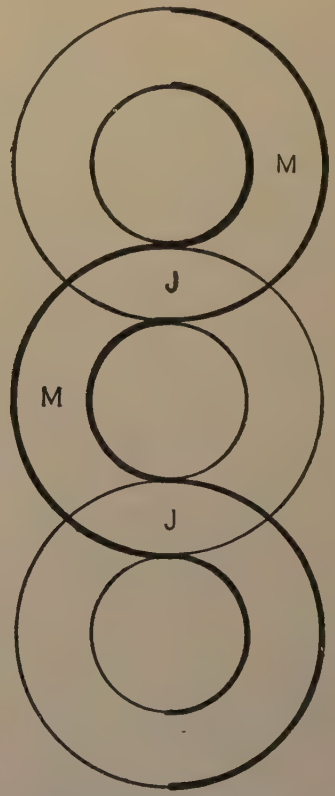


FIG. 43.—Diagrammatic representation of meandering river made up of parts of circles. If the figure is viewed from a low angle with the page held almost on a level with the eye, the effect represented by Fig. 42 is produced.

with the eye. This figure purports to be the map of such a river, the curves being true circles. When viewed from a low angle the circles appear as ellipses, and the effect is like that in Fig. 42.

29. A river cut very slightly below a plain.—To represent a river flowing slightly below the level of a broad, flat flood plain, the sweeping curves of the river are first drawn as in Fig. 42. These lines, unlike those used in previous examples, represent not the river itself but the top of the river bank. From these lines then are drawn short vertical

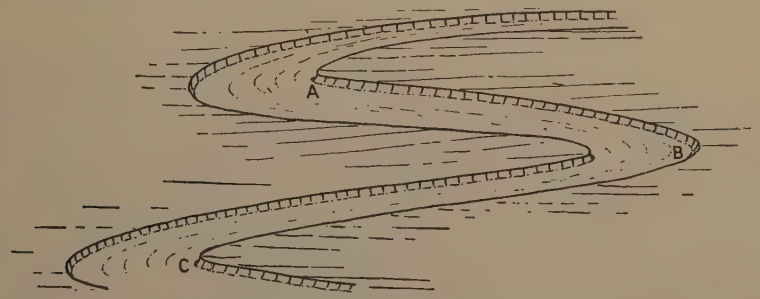


FIG. 44.—Representation of meandering river flowing slightly below level of flood plain.

or almost vertical lines which represent the low cliff bordering the river, as in Fig. 44. The short lines are drawn only on the far side of the river, because, unless the observer is looking across the stream, he is unable to see the river bank. Thus, between the points *A* and *B* the cliff is visible, but at *B* it disappears from view and is invisible between *B* and *C*. At *B*, therefore, no short vertical lines should be drawn beyond the point where they become tangent to the river bank. In Fig. 45 the incorrect method is shown and the result is unsatisfactory and meaningless.

30. Meander spurs.—A stream having large, sweeping curves or meanders usually shows steep undercut slopes on the upstream side and gentle slip-off slopes on the downstream side of the meander spur. These two features, the

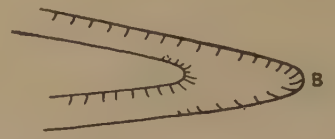


FIG. 45.—Incorrect method of representing river bank, properly done at *B* in Fig. 44.

slip-off slope and the undercut slope, are difficult to represent in the same picture if the observer is looking directly upstream or downstream as in Fig. 44; but they may be represented rather easily if the observer is off at one side of the river, as in Fig. 46.

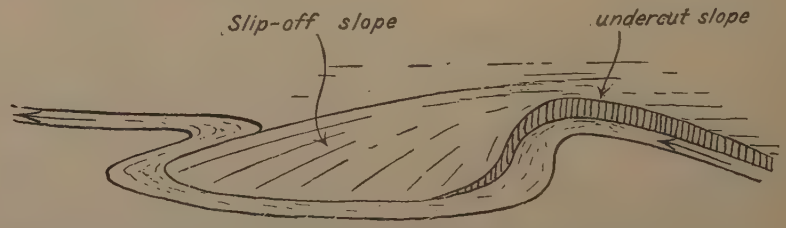


FIG. 46.—A meander spur, showing undercut and slip-off slopes; best represented by viewing the feature from across the stream instead of looking directly upstream or downstream.

31. A plain "creased" by a stream.—The most common type of topography is a plain below which streams have cut to only a slight degree. To produce this "quilted" effect, represent the streams coursing across the plain in the usual fashion, Fig. 47 *A*. Then, tangent to the apex of each curve

(as at X, Fig. 47 B), draw a line curving upward and flattening out to a horizontal position. These lines represent the profiles of the spurs around which the stream is flowing. Therefore, if, as at the point Y, Fig. 47 C, and Y, Fig. 47 D, these spur profiles overlap part of the stream, this portion of the stream should be removed as it is out of sight. But if,

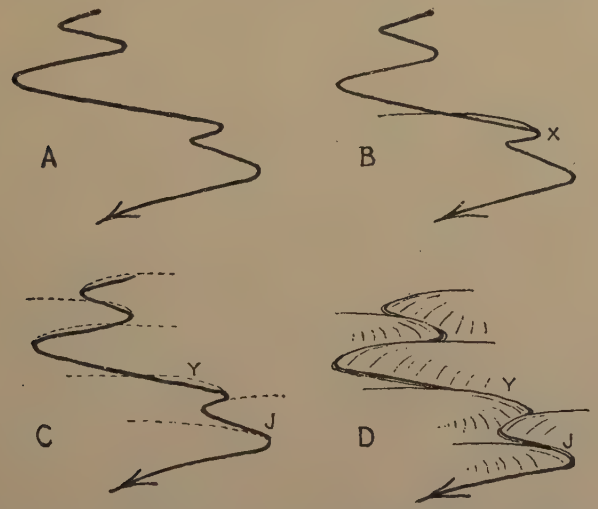


FIG. 47.—The representation of valleys cut slightly below a plain. The spur profiles are tangent to the curves as at X in sketch B, and flatten out at the top where they meet the surface of the plain.

as at J, Fig. 47 C and D, there is no overlapping, then this part of the stream remains in view. The drawing thus prepared may be further enhanced by shading the hill slopes as in Fig. 47, D. These shading lines should be drawn as if running directly down the slope, as hachures do on a map.

32. Shallow trenching and deep trenching.—Streams may be represented as but slightly intrenched if very slight curvature is given to the spur profiles as in Fig. 48, A and B. When, however, deep trenching is to be indicated the spur profiles should curve strongly as in C and D of Fig. 48. When this is done it will be noticed that the spurs overlap each other, and this in consequence causes the lower parts of the spurs to be hidden by spurs nearer to the observer. In other words, when the trenching is deep the stream is out of sight

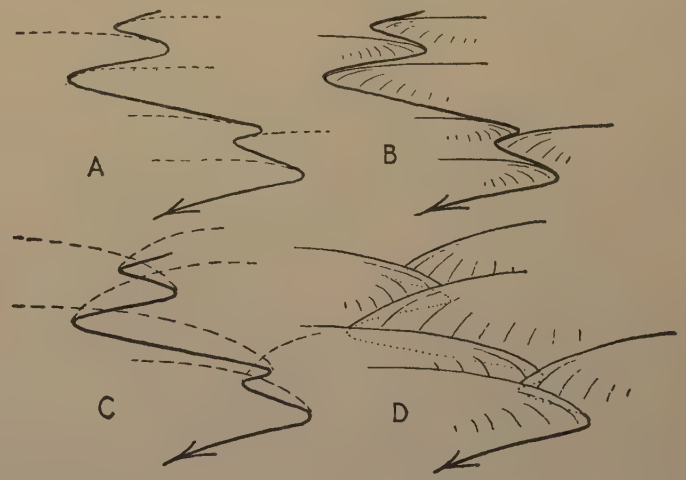


FIG. 48.—Shallow trenching is represented by the flat profiles in Figures A and B; deep trenching by the strongly curved profiles in C and D.

(Fig. 48, D), but when the trenching is shallow parts of the stream are visible (Fig. 48, B).

33. A young plain.—A plain cut by few streams still preserves most of its original surface. It is a young plain. The number of tributaries is small and much of the surface of the plain remains undrained. The divides are broad. The streams are likewise young, the valleys are narrow, and

the walls rather steep. These characteristics are expressed in Fig. 49. But the streams dissecting a young plain may advance so rapidly in development that they become mature before the plain has lost its youthful character. Thus in Fig. 50, *C*, the master stream of the region has a mature character; its valley is wide and it flows in a meandering course through a broad flood plain. Its tributaries are still young, and the plain remains in large part undissected.

Fig. 49.—A young plain with young valleys.

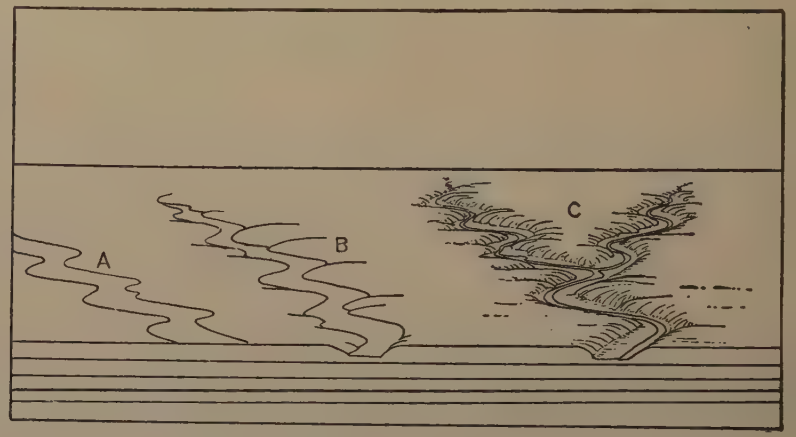


Fig. 50.—A young plain with mature valleys.

The drawing of the mature valley is accomplished in a manner similar to the drawing of a simple stream, except that two lines are first drawn (Fig. 50, *A*), one for each side of the valley. Then each line is treated in the appropriate manner, as shown in Fig. 50, *B*.

34. Specific example: young plain. Trent River quadrangle, North Carolina.—Figure 51 suggests a very simple rendering of this map. It is presented as the type of drawing which might be helpful to the younger student. Such a drawing can readily be placed on the blackboard by the instructor and, in spite of certain crudities and omissions, it gives a touch of life to the lesson. It presents to the beginner a mental picture of what is meant by a young plain. It shows him that a great deal of the plain is still untouched by streams and, studied with the map, it shows that much of the upland surface is so poorly drained as to be marshy. Such a condition does not exist where the drainage is more perfectly developed. Another result of this undissected condition is expressed in the straight roads and railroads, one railroad running some fifteen miles across the map without a curve. Such towns and settlements as do exist are on the upland rather than in the stream valleys, because it is on the upland that communication is best developed.

A hint to the teacher upon preparing a drawing of this

kind would be to omit irrelevant details, emphasize the few points that are to be especially stressed, and remember that a block diagram is a device, a tool, which should serve the teacher as he wishes and not make a slave of him by creating an undue respect for details.

35. Specific example: plain in late youth. Wilson quadrangle, North Carolina.—The representation of a plain somewhat further advanced in development than that shown in Fig. 51 is represented by the Wilson sheet, Fig. 52. The valleys. The process of drawing two wavy lines to represent the two sides of a wide valley, as shown in Fig. 50, was not literally followed, but a similar effect was obtained by having in mind the general character of such a valley.

Most of the maps of the Atlantic coastal plain could be used in drawing block diagrams of young plains: such for instance as the Falkland and Winterville sheets, North Carolina; the Hurlock and Denton sheets, Maryland; and the

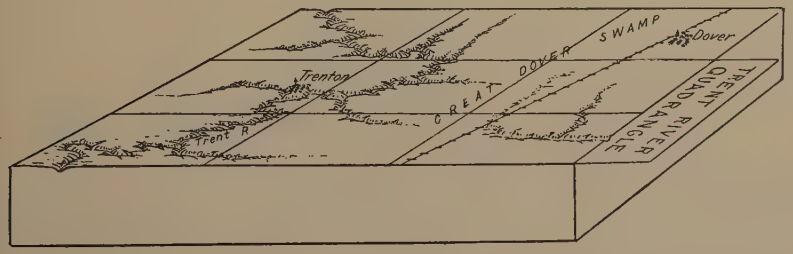


FIG. 51.—Block diagram of the Trent River quadrangle, North Carolina. A young plain.

FIG. 52.—Block diagram of Wilson quadrangle, North Carolina. A plain in late youth.

main stream of the district, Contentnea Creek, has already attained maturity, but most of its tributaries are still young. The plain as a whole is much more dissected than that shown in the Trent River quadrangle, so that much less of the flat upland remains. This may be due to the fact that the Wilson area is a more inland portion of the coastal plain, that it was uplifted first, and has been longer subjected to erosion. Even so, the upland still serves as the site for towns. Railroads and roads select the upland rather than the valleys and are very slightly interrupted in their straight courses by the topography. It will be noted in Fig. 52 that somewhat more freedom has been exercised in representing the Wicomico sheet, Maryland-Virginia. This last shows a somewhat more advanced stage than the others.

36. A mature plain.—The representation of a mature plain is suggested in Fig. 53. In the right-hand part of the drawing the device used is the same as in Fig. 49, but many more tributaries are introduced. The result is that the plain is thoroughly dissected. All slopes lead toward the streams, and there are no extensive undrained areas as in young plains. At the left in Fig. 53, a simpler, somewhat conventional, and more easily drawn device for representing a maturely dissected plain is presented. The foreground shows the horizontal structure of the plain.

37. Specific example: mature plain. Elk Point quadrangle, South Dakota-Nebraska-Iowa.—This region will be found especially suitable as an example of a mapped area which may be transformed into a block diagram. In the Elk Point Folio, No. 156, of the U. S. Geological Survey, there are given two cross-sections showing structure. Thus, with the aid of the geological map a very accurate and detailed drawing may be made. In Fig. 54 the structure of this quadrangle with the names of some of the formations is shown, but a larger drawing would make possible still greater detail.

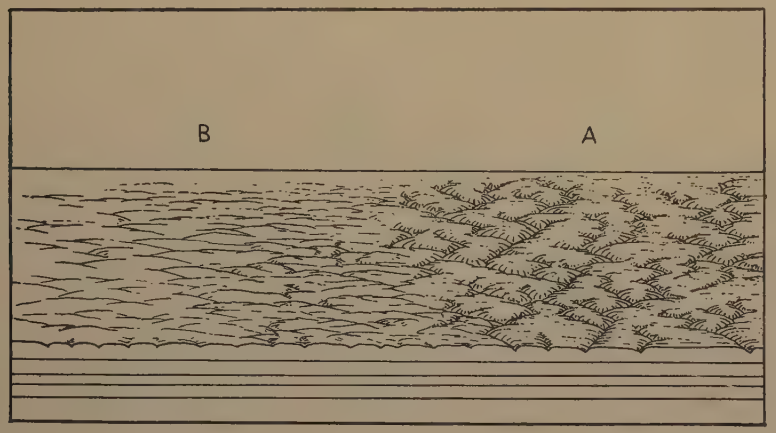


FIG. 53.—Representation of maturely dissected plain, showing two methods of indicating relief.

The upland on either side of the Missouri valley is maturely dissected by streams which are still young. The broad valley of the Missouri River, however, is a splendid example of a mature valley and the Big Sioux valley is similar in this respect. It will be noted that the main railroads of the region follow the floors of these broad valleys and the largest towns likewise are located there. Other points of interest are the ox-bow lakes like Lake Goodenough, McCook Lake, and the marsh at Elk Point, representing old meanders of the Missouri River. Worth noting also is the peculiar parallel course of the Big Sioux River on the side of the

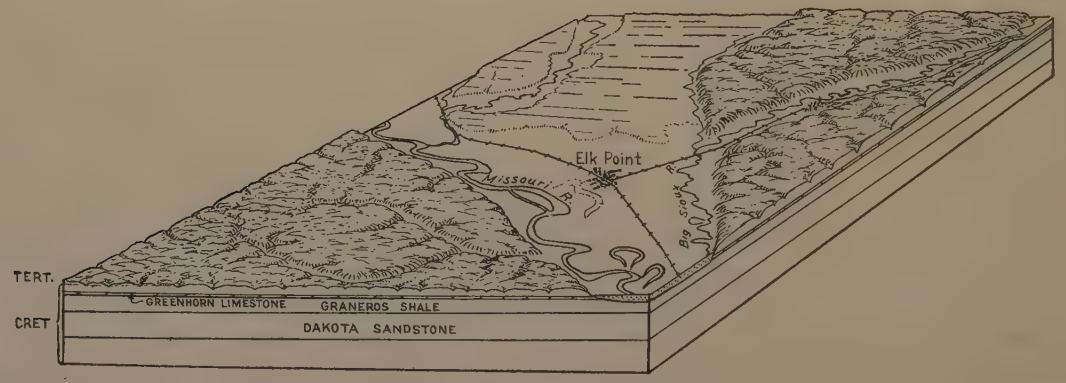


FIG. 54.—Block diagram of Elk Point quadrangle, South Dakota. A plain maturely dissected by youthful streams tributary to mature stream.

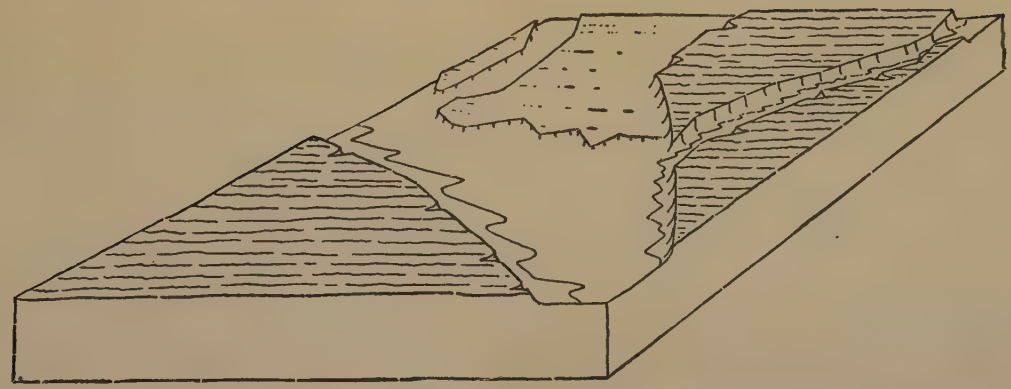


FIG. 55.—Freehand sketch, basis for blackboard illustration of Elk Point quadrangle, more carefully drawn in Fig. 54.

Missouri flood plain. This is due to the fact that, in building up its flood plain, the Missouri River forces its tributaries over to the valley wall in the same way as the Mississippi has done with the Yazoo River.

The teacher wishing to represent hastily a region of this kind upon the blackboard will do well to follow some such method as that advanced in Fig. 55. If the upland outlines are represented in a more or less angular fashion they can be drawn rather quickly, and the whole drawing, in spite of its crudity, will convey to the student a helpful picture. Other maps which will serve as examples of maturely dissected plains are the Iuka, Mississippi-Alabama-Tennessee quadrangle, and the Patuxent, Maryland-District of Columbia quadrangle.

38. An old plain.—It will be noted in Fig. 53 that a mature plain represents the most rugged stage in the dissection of the plain. After this stage is passed the region is worn down again to a rolling lowland in which low hills here and there are the only evidence of the former level. Such a condition is represented in Fig. 56. Type examples of this stage are difficult to find in nature, because most old plains have later been rejuvenated. Perhaps maps like those of southern Arkansas and adjacent parts of Oklahoma approxi-

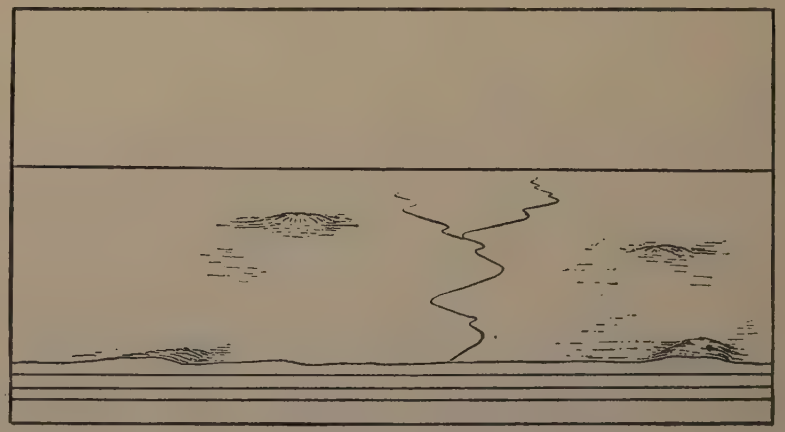


FIG. 56.—An old plain with scattered residuals.

mate this condition as closely as any. The Canadian, Oklahoma, sheet may be mentioned as one of them.

39. Plateaus. The use of solid geometrical forms as bases for topographic features.—Plateaus, mesas, and tablelands may be developed from artificial-looking rectangular blocks. In fact, it may be noted here that in the representation of all the land forms which follow—not only plateaus, but dome mountains, folded mountains, block mountains, as well as the apparently disordered features produced by glacial erosion—it will be found advantageous to reduce these forms first to some geometrically simple pattern. Forms common to mechanical drawing, and made up of straight lines, square-edged blocks, wedge-shaped blocks, cylinders, cones and spheres, are readily drawn in perspective, whereas a systemless maze of canyons, peaks, and valleys is likely to bewilder the novitiate. These simple, geometrical forms are then readily elaborated, and by smoothing down the awkward places and adding some detail a certain naturalness is readily imparted to a drawing which a few moments before was quite unconvincing in appearance.

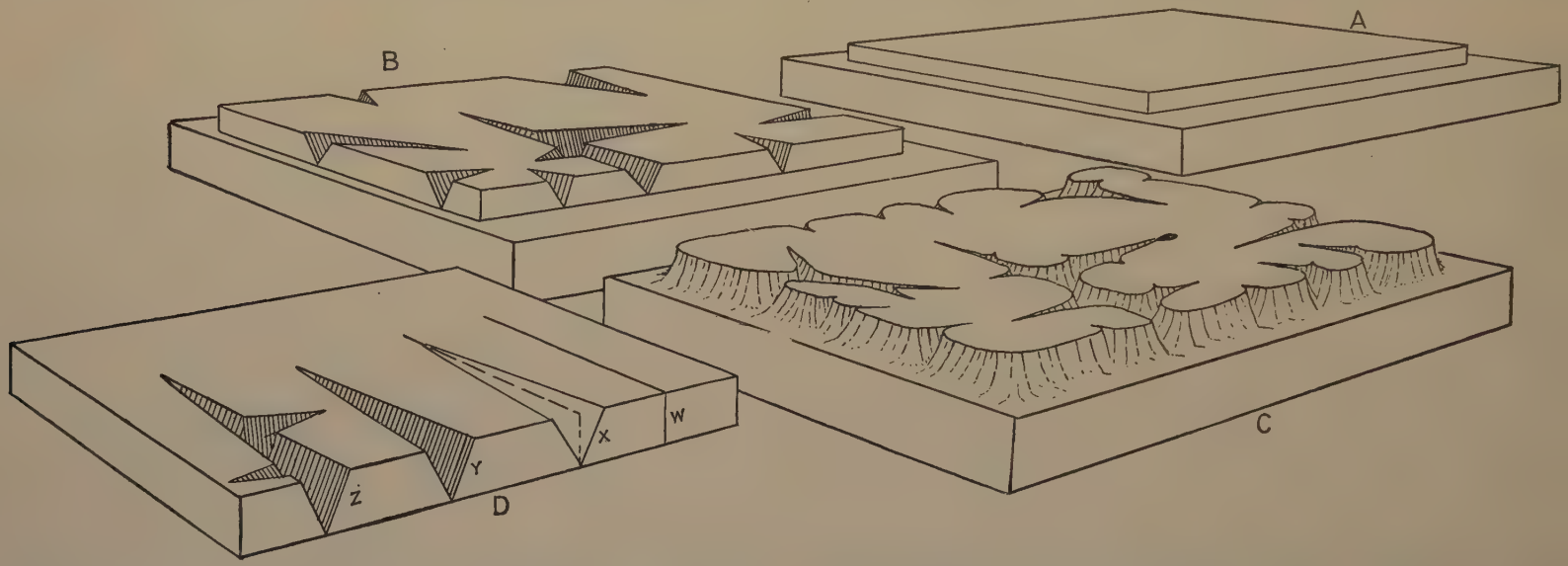


FIG. 57.—Blocks to show several stages in the representation of a dissected tableland. Block *A*, before dissection; block *B*, gorges and canyons represented by straight lines; block *C*, same with corners rounded. Block *D* shows how to draw a gorge by drawing the medial line *W*, then the valley walls at *X*, and later shading the slopes.

40. A tableland slightly dissected.—A rectangular block serves as the mass out of which may be carved the features of a plateau. In Fig. 57 the several stages in this whittling-out process are shown. Block *A* represents the undissected

block. Block *B* is the same block notched by a number of gorges, all features being shown mechanically with straight lines. Block *C* represents the same area with some of the angularities rounded off and a few minor details added. As the drawing of streams and notches of this character will be demanded of the student in the representation of many of the succeeding types of land forms, it is worth while to note some of the essential principles of construction. Block *D* in Fig. 57 shows the several stages in the drawing of a single notch. First a single line, *W*, is drawn to represent the medial position of the valley. Then the valley walls are drawn, as at *X*, so that at the mouth of the valley they are equidistant from the medial line. The valley side may then be shaded as shown, and tributaries added, as at *Y* and *Z*. Medial lines for the tributaries are drawn the same as for the main stream. This procedure may seem rather artificial inasmuch as streams never have such regular shapes; but the student will find that, by establishing something uniform and definite in his mind, he will have a tangible picture from which he can readily depart in order to produce the more intricate forms of nature.

41. Young, mature, and old plateaus.—Figure 58, *A*, *B*, *C*, *D*, *E*, *F*, shows simple methods of presenting the characteristics of a plateau in different stages of dissection. Any of these views may be transformed into rectangular block form if desired, without altering the representation of the surface features. The method used here, however, conserves space, whereas the block form, although often more attractive to the student, sometimes requires more room on the page than it is justified in using. The first tier of drawings, *A*, *B*, and *C*, in Fig. 58, represents the stages of a plateau in a more or less arid region where the valleys are canyon-like with sharply cut walls. The second tier, *D*, *E*, and *F*, represents a more humid region, with the valley walls

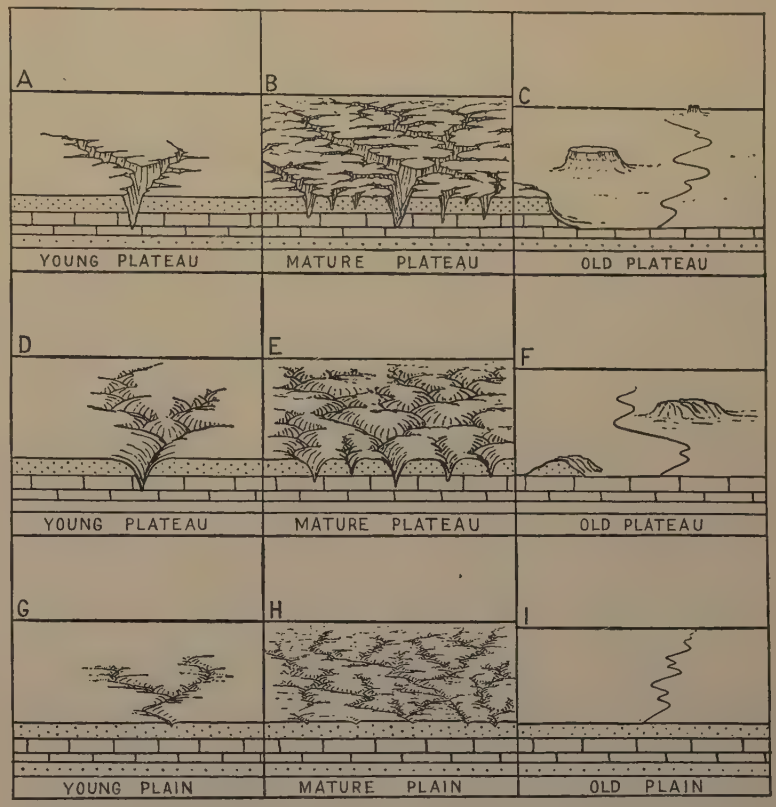


FIG. 58.—Simple method of showing comparison between young, mature, and old plains and plateaus.

rounded. The general aspect of such a country would be quite different because of the more abundant vegetation. In the third tier, *G*, *H*, and *I*, the more gentle features of a plain

are shown for comparison, the essential difference between a plain and a plateau being the difference in the depth to which dissection has gone.

The arrangement in Fig. 58 is introduced to show the value of making comparisons. A drawing is more than doubly enhanced in value if it becomes a member of a series. Professor Davis has shown great skill and taste in presenting series of from two to six or more drawings as part of the same figure, in order that the eye, and consequently the understanding, may be carried from one to the other with as little inconvenience as possible. Good examples of this, to which the ambitious student may refer, are to be found in his *Beschreibung der Landformen:* Fig. 23, the development of valley slopes; Fig. 58, the influence of contrasted structures upon the stage of development; Fig. 96, the development of a belted coastal plain; Fig. 188, the development and destruction of a barrier beach. Figure 1 illustrating his paper on the Rocky Mountain Front Range is another good example.

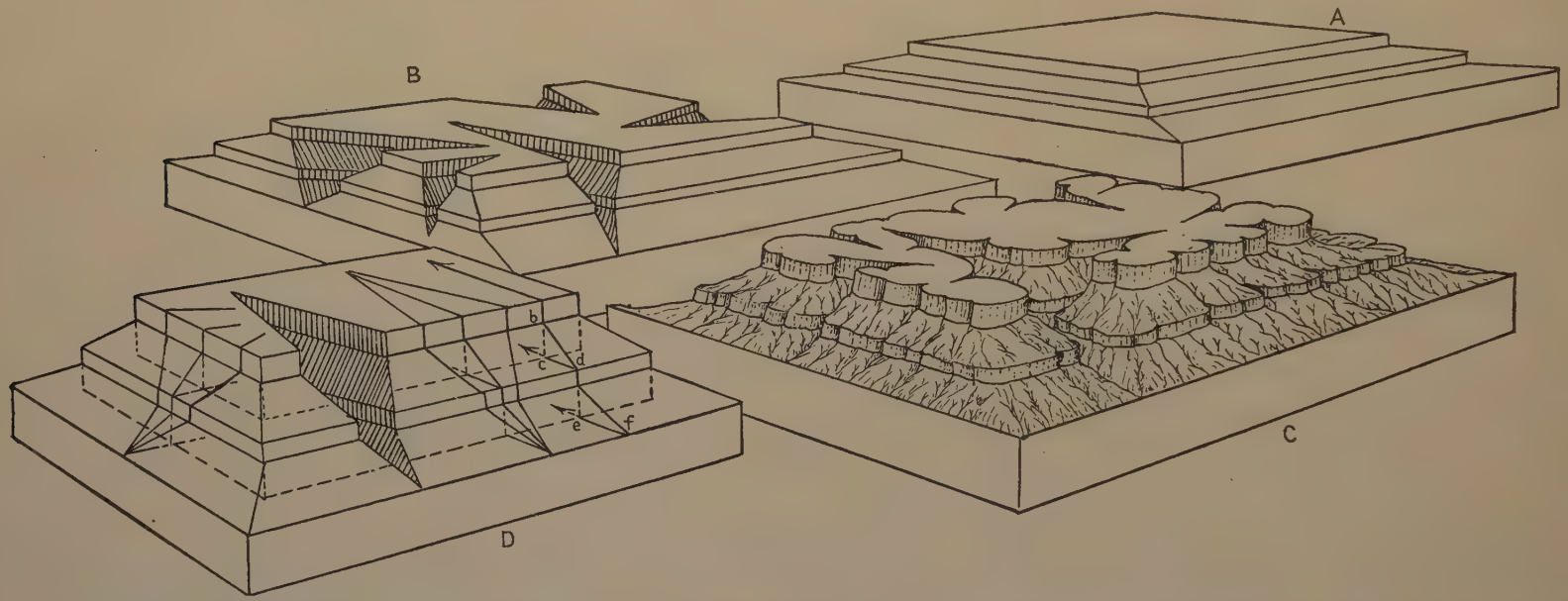


Fig. 59.—Blocks to show several stages in the representation of a dissected tableland made up of several hard and soft layers. The method is completely described in Section 42 of the text.

42. Plateaus and canyons of a more complicated character.—The plateaus just indicated suggest uniformity of structure throughout, whereas usually there is an alternation

of resistant and weak beds. The resulting terraces and steps in the erosional forms may readily be represented if the forms are reduced to conform with some simple geometrical pattern.

In Fig. 59, block *A* represents the block out of which the plateau features are to be carved. Two hard formations are represented, each underlain by a softer member. Block *B*, similar to block *B* in Fig. 57, shows the plateau cut by a number of notches or canyons, and block *C* shows the same with the angularities rounded off, and with a few details added. Block *D* shows several stages in the representation of the notches. At first a medial line is drawn. This is done accurately by projecting each hard formation down through the underlying soft series to the top of the next hard formation and making use of the construction lines *bc*, *cd*, *de*, and *ef* to determine the points *d* and *f*. These construction lines readily explain themselves. The lines *bc* and *de* are drawn vertical; *cd* and *ef* are directed toward the vanishing point, far away at the left.

The artificial appearance of the plateau may be still further overcome by the use of greater freedom in representing details; but it is nevertheless very desirable at the outset to block out the drawing along geometrical lines. Modifications may then readily be introduced. This is better than to think in terms of details and overlook the essential form of the larger mass. Fig. 60 is a liberal application of the principles here set forth. It is a sketch, but also may be conceived as a part of a block diagram whose sides are outside of the view. A picture of this kind, whether drawn from a photograph or sketched in the field, may be transformed into a block diagram of any shape desired. The

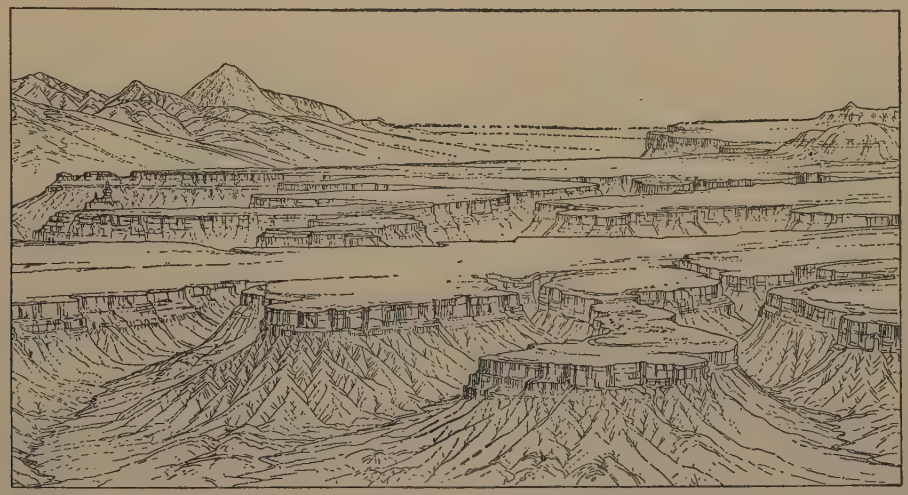


FIG. 60.—Picture of a submaturely dissected plateau, the Mesa Verde, in Colorado. (U. S. G. S.)

representation of a cross-section on this sketch is shown in Fig. 61. The problem of cutting out a block in either two-point or one-point perspective is left to the student as a suitable task for the exercise of his acquired skill.

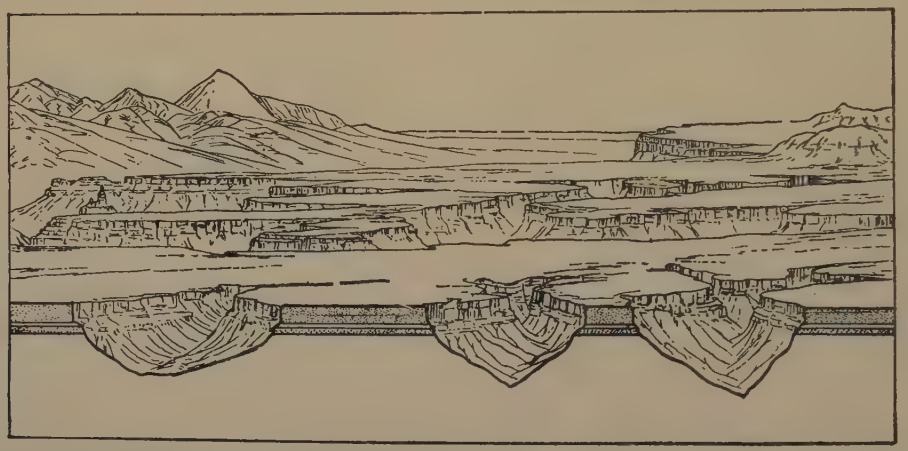


FIG. 61.—The same as Fig. 60 transformed by placing a cross-section through the front part of the picture in order to show geological structure. Any picture can be altered in this manner.

43. Specific example: young plateau. Part of Watrous quadrangle, New Mexico.—Figure 62 represents the southeastern corner of the Watrous quadrangle. The features are portrayed in a purely diagrammatic manner with considerable

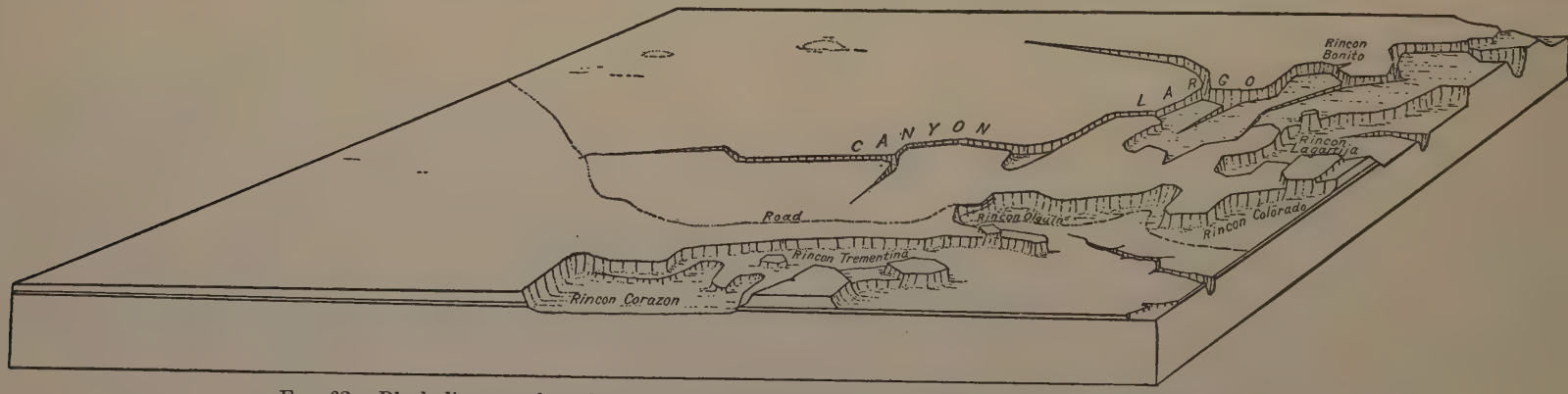


FIG. 62.—Block diagram of southeastern corner of Watrous quadrangle, New Mexico, a young plateau.

angularity. In this case, because of the natural sharpness of the topographic forms, the departure from nature is not unduly great. It will be noted that there has been no slavish regard for details. The essential element of the topography to which especial attention should be directed is the step, terrace, or bench-like arrangement of the canyon walls, revealing definitely the horizontal rock structure. There is no topographic map which displays such diagnostic characteristics better than this one. The canyon of Mora River in the central part of the Watrous sheet would also serve as an admirable subject for a block diagram, similar to Fig. 62, but somewhat simpler. The outer and inner walls of the canyon, due to differential erosion on horizontal structure, are remarkably well shown.

The Marsh Pass sheet, Arizona, reveals horizontal structure almost as satisfactorily, especially the canyons in the northern part. In fact this entire sheet would make an admirable and instructive drawing. In the southern half of the map, Zilh-Le-Jini mesa is a great plateau slightly warped down toward the center so that it is essentially a flat syncline pitching gently southward.

The Mesa de Maya sheet, Colorado, provides another splendid example of a young plateau. Less rugged than this is the Macomb quadrangle, Illinois, which represents a very young plain or plateau, the relief being much slighter than in the previous examples.

44. Specific example: mature plateau. Scottsboro sheet, Alabama.—As an example of a maturely, or better, a submaturely, dissected plateau, this sheet is most useful. The drawing, Fig. 63, represents the entire quadrangle. It is strictly diagrammatic like Fig. 62 and may serve to suggest still further a method of treatment which will be found advantageous. The omission of details not only conserves time in the preparation of the drawing but frees the drawing of the distractions which would otherwise obscure the essential facts. A drawing of this character can readily and hastily be placed on the blackboard by the teacher without undue sacrifice of time. Although no apologies are here intended, nevertheless it should be emphasized that this type of drawing lacks a certain degree of elegance which can be attained only by the application of care and a critical study

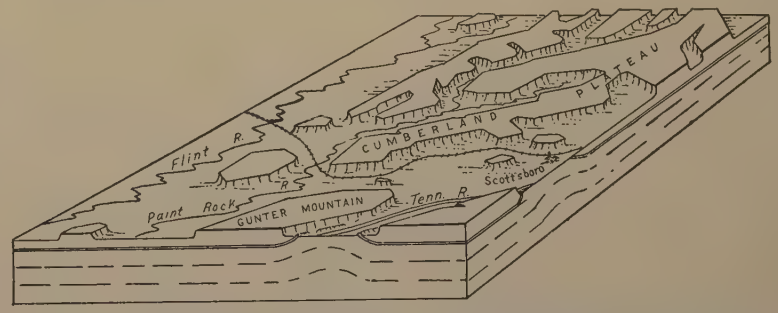


FIG. 63.—Block diagram of Scottsboro quadrangle, Alabama. A maturely dissected plateau. A simple and purely diagrammatic method of presentation, useful for hasty blackboard drawings.

and balance of details. From the map alone one would hardly be expected to know the anticlinal structure of the Tennessee valley although the longitudinal ridges are distinctly represented by the contours.

Another example of a mature plateau is furnished by the Iaeger quadrangle, West Virginia-Virginia, and other sheets in that vicinity. The representation of this area might better follow some device like that used in Fig. 58, *E* or *H*, than the harsh angular method of Fig. 63 or the canyon symbol of Fig. 58, *B*.

45. Specific example: old plateau. Goshen Hole, Scotts Bluff and Camp Clarke sheets, Nebraska.—The area comprised in these maps may be considered an old plateau. The mesas in the middle are the remnants of the formerly continuous surface, now represented elsewhere only on the southern and northern margin of the sheets. The illustrations in the Scotts Bluff and Camp Clarke folios will serve as guides to the type of topography here represented. The portrayal of this area, either one sheet, or the three sheets together, is left as an exercise for the student, who will find it a most admirable subject.

46. A canyon viewed from below its margin.—In all the plateaus thus far presented, the observer is well above the highest point and looks down upon everything in view. Sometimes, however, it is desirable to draw a canyon as seen from below its rim, as in Fig. 3. A view of this kind loses its resemblance to most block diagrams and becomes essentially a picture or sketch. But, as mentioned before, any sketch can be turned into a diagram shaped like a block and providing faces for structural cross-sections.

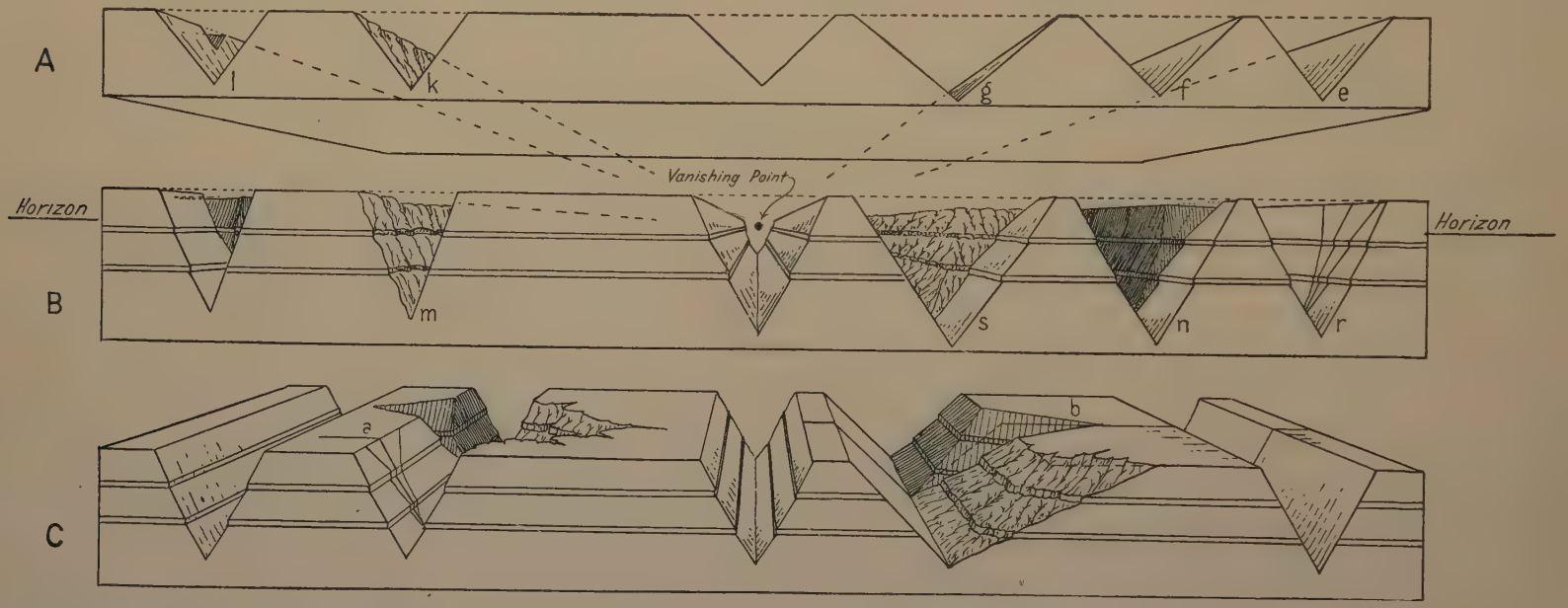


FIG. 64.—Canyons drawn in different positions relative to the observer. In *A* all of the canyon is above the observer; in *B* the top of the canyon is above the observer, the bottom is below; in *C* all of the canyon is below the observer.

Figure 64 represents three blocks, *A*, *B*, and *C*, drawn in one-point perspective. All of block *A* is above the

observer's eye. The surface of block *B* is also above the observer's eye. The vanishing point is on the horizon in the center of the picture. To this vanishing point are directed all lines at right angles to the plane of the picture. That is to say, all of the canyons and valleys shown on the three blocks, except the small tributary notches, trend in a direction at right angles to the front of the block. The canyon walls are drawn toward the vanishing point in every case, but it will be noted that the appearance of the canyon depends to a great extent upon the position of the block in which it is cut. Obviously it is not easy to foresee all the difficulties which may arise and to suggest means by which they may be overcome; but it will be helpful to the student, in looking over the three blocks in Fig. 64, to note such points as the following:

1. The canyons farthest to the right and left of the observer present to view a larger area of wall space than those in the middle of the block. This is true whether the canyon is viewed from above or below. Therefore some position like *a* or *b* in block *C*, or *m* or *n* in block *B*, or *e*, *f*, *k*, or *l* in block *A*, renders it possible to express more detail on the canyon walls, such as tributary gorges, than would a position in the center of the drawing.

2. The drawing of tributary gorges is aided by drawing first a medial line, in the manner suggested in Figs. 57 and 59. Thus in Fig. 64, block *B*, the three canyons, *r*, *n*, and *s*, show first in *r* the medial line with the edges of the notch outlined, then in *n* the walls shaded as plane surfaces, and finally in *s* the canyon sides broken up by numerous gullies.

47. A coastal plain. The block.—The usual purpose in drawing a coastal plain in block form is to provide a graphic means for explaining the successive stages in the development of coastal plain features. That is to say, the diagram serves to illustrate the deductive method of treatment. This is likewise true in the use of block diagrams to illustrate the development of block mountains, dome mountains, folded mountains, and other constructional land forms.

Figure 65 shows in the background a simple undissected block from which the coastal plain features roughly represented in the foreground are to be carved. The drawing

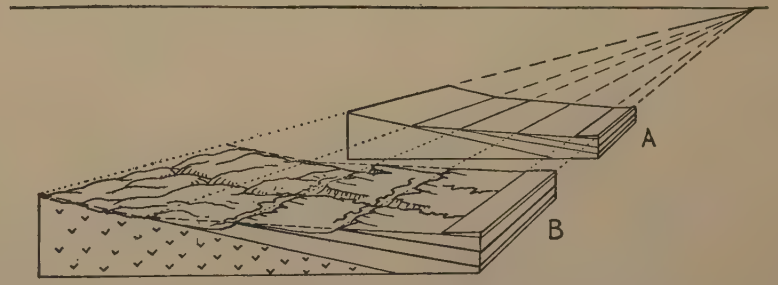


FIG. 65.—Coastal plain in one-point perspective. Block *A* shows the method of laying off the block which later may be modified by stages to indicate the successive forms which lead to the condition represented in block *B*.

makes use of the one-point system of perspective because this gives a full cross-section at the side of the block. As a good understanding of the geological structure is indispensable to a clear comprehension of the features produced by erosion, it is highly desirable that a good full view of the side of the block be presented to the observer, and consequently the one-point system is used.

Figure 66 shows again the undissected block, with certain invisible lines indicated by dots. In the preparation of the block, the front cross-section should be drawn first and the block built on to it. The construction lines are necessary in

order to determine the position of points *m*, *a*, and *b*, and the slope of *ma*, and *ab*.

Figure 67, *A*, represents a similar block with some modification in the attitude of the sedimentary beds constituting the coastal plain. Either of these drawings, Fig. 66 or Fig. 67, *A*, will serve as a block from which may be carved the features of a dissected coastal plain. If Fig. 66 is used it will be noted that the lowlands subsequently developed upon the exposed edges of the softer beds are all

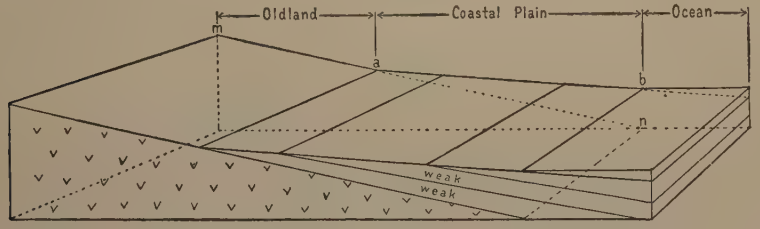


FIG. 66.—Outline of block for coastal plain, in one-point perspective; to show construction lines necessary in drawing the block.

formed simultaneously. But in Fig. 67 the highest or outermost cuesta must be pushed far seaward before opportunity is offered for the development of a cuesta upon the next resistant formation beneath. This development is represented in Fig. 67, *B* and *C*.

A criticism may be offered against the drawings used in Fig. 67 to the effect that they occupy too much space. There is lack of compactness, a matter which is important for textbook illustrations. The drawings in Fig. 67 are suitable for blackboard use, however. Block *A* is readily drawn freehand upon the blackboard. The various stages leading up to *B* and *C* may then be shown by erasing the parts already drawn so that the student observes the actual change from one phase to another. This, however, can not be done on the illustrated page, but some device like Fig. 68 serves the same purpose. It is compact and shows the change in development from the very youthful condition prevailing in the

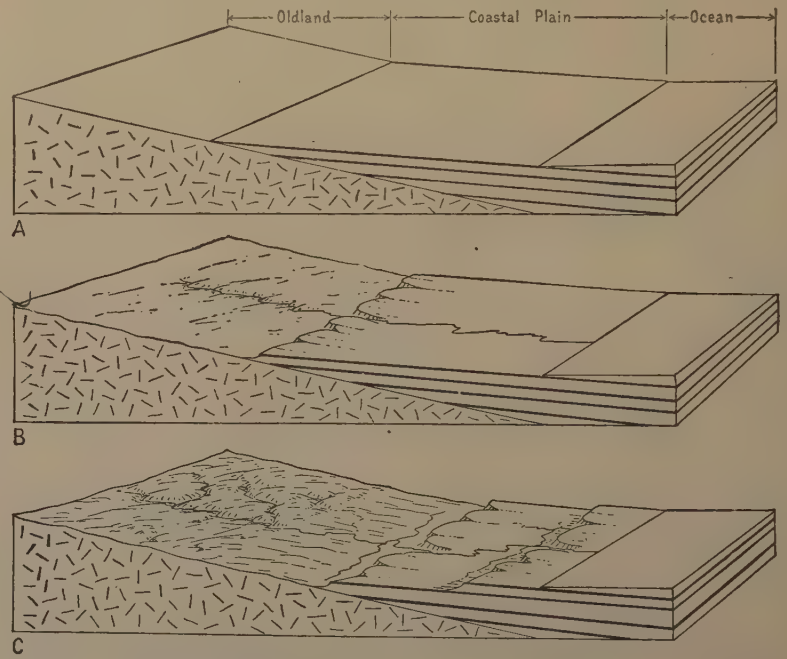


FIG. 67.—Successive stages in the erosion of a coastal plain, shown in one-point perspective. The cross-section of the coastal plain differs from the one in Fig. 66 in that the formations overlap landward, with the result that the subsequent lowlands are not formed simultaneously.

back part of the drawing to mature dissection in the front. The different types of streams are indicated by an initial letter: as consequent, *C*; extended consequent, *EC*; subsequent, *S*; resequent, *R*; and insequent, *I*. The outer low-

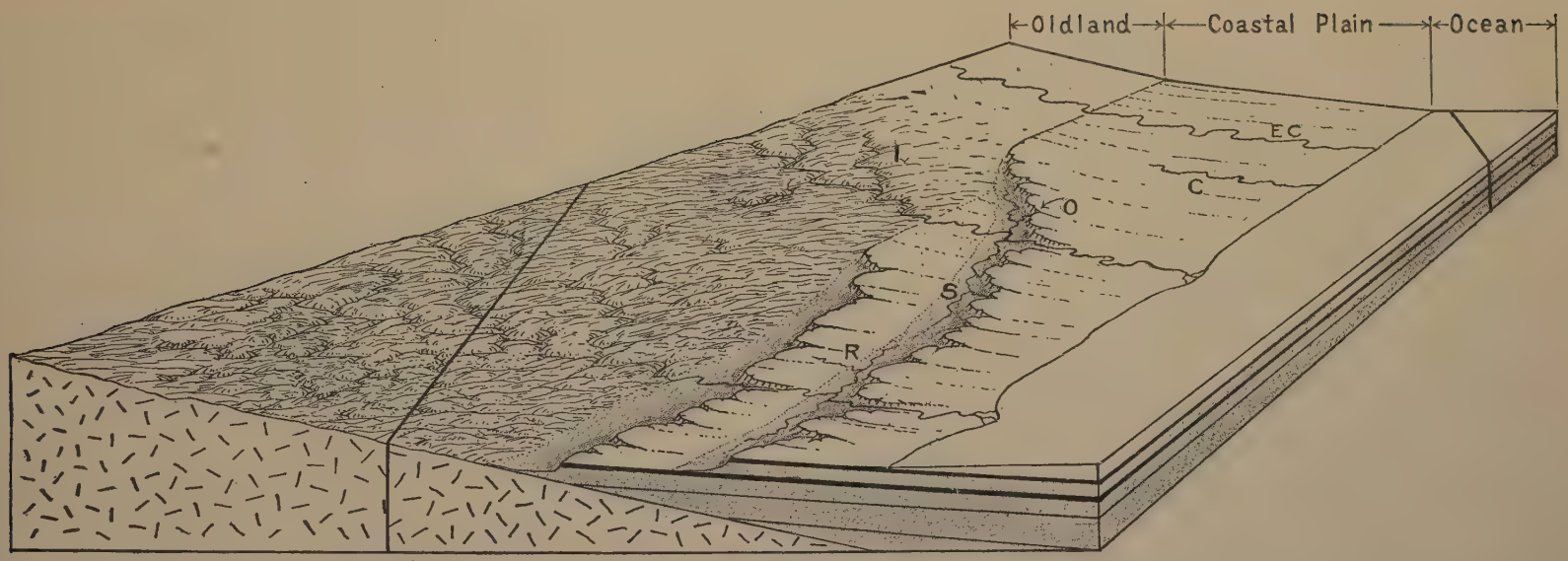


FIG. 68.—Block combining in one illustration the several stages represented separately in Fig. 67. The heavy lines at the right and left show how these useless corners might be eliminated to save room.

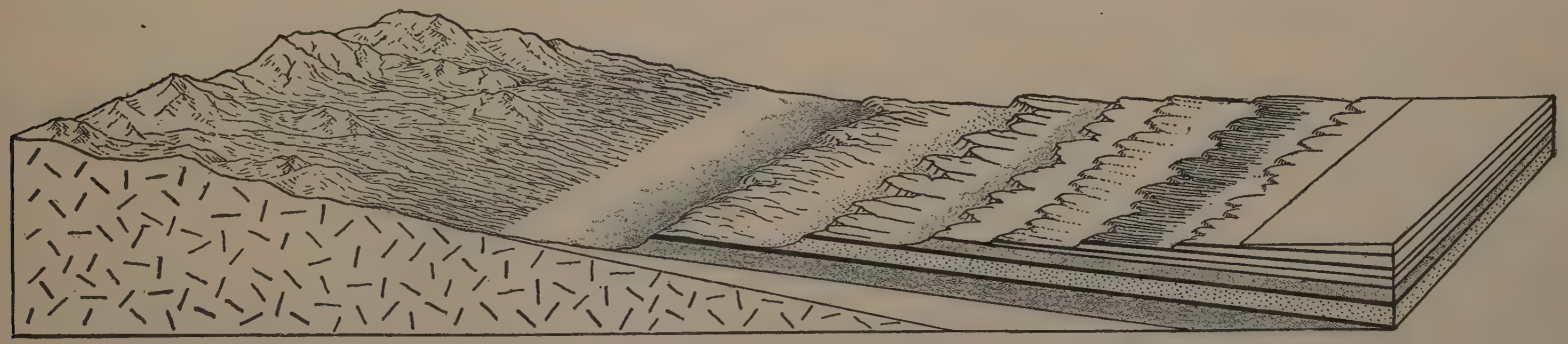


FIG. 69.—Block drawing to illustrate several methods of representing cuestas in order to give each one an individuality of its own.

land, the inner lowland, the fall line, the cuestas, wind gaps, beheaded and inverted streams may be similarly labeled. It is suggested that drawings like Fig. 68 can readily and cheaply be reproduced in quantity for laboratory use so that each student may supply on his individual copy the names of different features and types of streams. Fig. 68 may be further improved by eliminating the corners at the right and left as suggested by the heavy lines. This makes it possible to reproduce the important portion on a larger scale or to utilize it so that less room on the printed page is required.

48. The coastal plain. Differentiation of cuestas produced by differing rock layers.—Cuestas vary in character owing to the differences in the rocks which produce them. Some cuestas are distinct escarpments; others are more rounded and flowing in outline. It is usually worth while to suggest these differences, and by judicial shading it will be possible to give a distinct character to each cuesta, as suggested in Fig. 69. Davis does this with great skill, as in his *Beschreibung der Landformen*, Fig. 99.

49. Specific examples: cuestas of mature coastal plains.—*a.* New Jersey. *b.* England. *c.* France. *d.* Wisconsin and New York. *e.* Germany and Sweden.

a. Figure 70 presents in skeleton form a block diagram representing four topographic maps of New Jersey. These maps may be studied in connection with the geological map of the state and thus a very detailed diagram, indicating each geological formation in cross-section and in outcrop, may be prepared. The diagram here shown is simple and generalized but suggests the way the drawing should be laid out. The labeling of other features, such as the streams, the individual hills, and Sandy Hook, and the introduction of smaller towns, might serve to give more realism to the drawing. The purpose for which the sketch is made should determine the data to be indicated. If it is to illustrate the geology, then all formations should be represented and labeled and the outcrops dotted in, even though no control

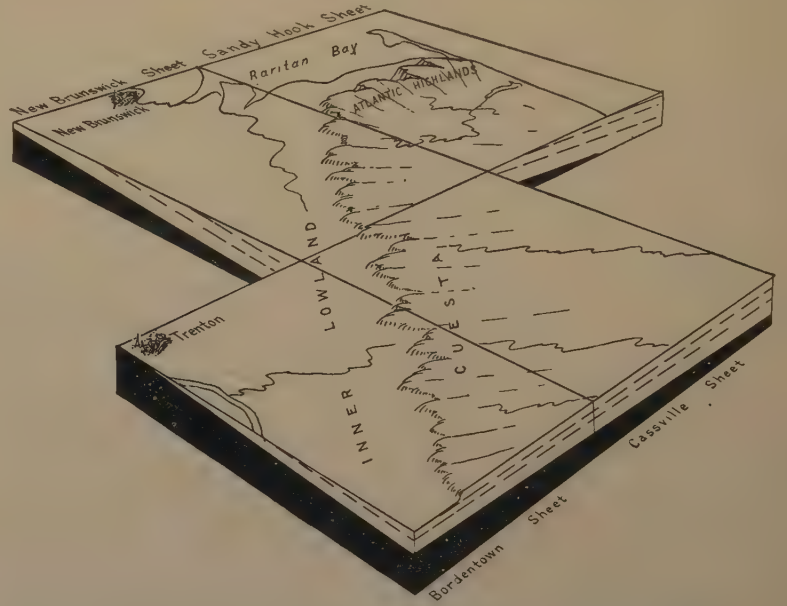


FIG. 70.—Block diagram in two-point perspective showing topography of four quadrangles in the coastal plain region of central New Jersey.

is exerted upon the topography. On the blackboard these formations can readily be colored. For laboratory and individual use students could be provided with simple outline drawings similar to Fig. 70, and be required to represent the outcrop of various formations, using different degrees of shading, colored pencils, or water color. A most instruc-

tive diagram would comprise a larger area, such as all of New Jersey, unless a very detailed problem were under consideration.

If the purpose of the drawing is to bring out certain human relationships, then more towns should be shown, as well as the chief railroads and roads. Types of soil, the occurrence of mineral deposits, and forests are only a few of the numerous subjects which might be emphasized.

b. In Fig. 71 a part of the coastal plain of England is shown. Three of the British Ordnance Survey sheets are represented, Nos. 104, 105, and 106 of the large sheet series published in colors on a scale of one inch to a mile. These maps represent only a narrow strip across the English coastal plain. With the geological map the larger relationships are made clear. Blocks *A* and *B* in Fig. 71 represent two different points of view of the same area. Block *A* is the better selected one because the edges of the escarpments are seen from the front. Thus they are not only more readily drawn, but also appear more real. In the cross-sections the oldland is filled in solid black. Many of the other British maps are equally suitable. A very simple one is the Lincoln sheet, No. 147 of the same series, showing a north-south escarpment formed on a slightly eastward-dipping bed.

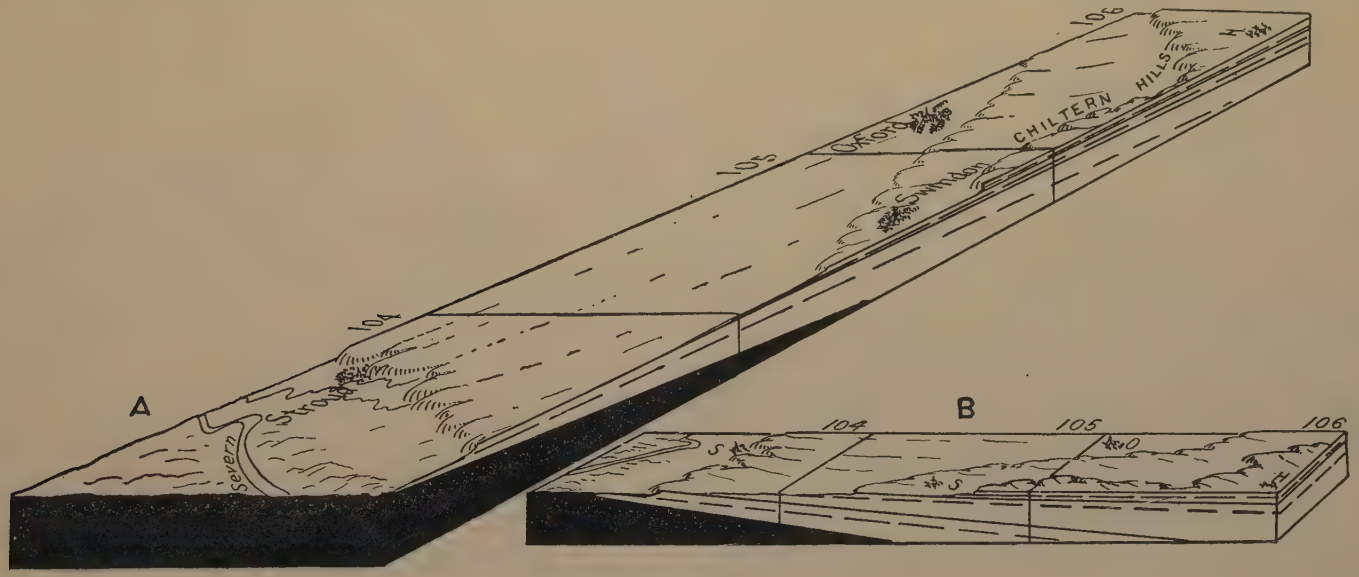


FIG. 71.—Block diagrams of part of southern England, vicinity of Oxford, showing coastal plain topography; representing sheets 104, 105, 106 of the British Ordnance Survey (large sheet series, one inch to a mile). Block *B* represents the same area as block *A*, viewed from a different angle.

c. The maps of France on scales of 1: 80,000 and

1: 200,000 offer equally good examples. These, studied in connection with the geological map of France, provide numerous opportunities for the preparation of block diagrams illustrating the characteristic cuestas of a coastal plain. The Rheims sheet, No. 34, and the Dijon sheet, No. 112, of the 1 : 80,000 map are two of the best examples. Fig. 72 represents sheet No. 17 Chalons and No. 18 Metz of the 1 : 200,000 map. These display a belt from the oldland

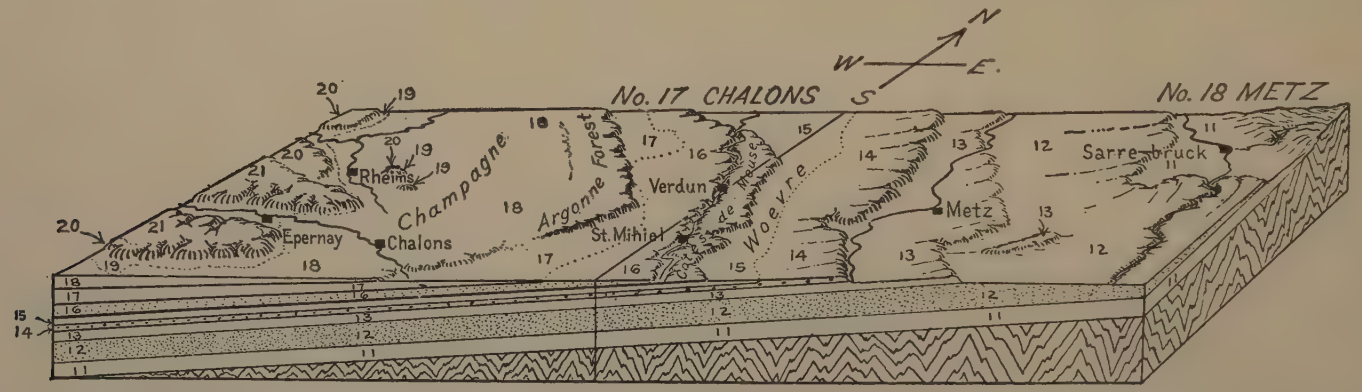


FIG. 72.—Block diagram of part of eastern France, showing the cuestas of the Paris Basin. Representation of Chalons Sheet No. 17, and Metz Sheet No. 18 of the French map 1 : 200,000. The figures refer to the formations numbered on the geologic map of France, scale 1 : 1,000,000.

at the base of the Ardennes on the east almost to the center of the Paris Basin on the west. Use of the geological map of France, scale 1: 1,000,000, has made it possible to number the formations on the diagram to correspond with the numbering on the geological map. A diagram of this type, while primarily useful to show the relation between surface features and underground structure, can have a much wider application. It can serve as a base for the location of railroads, roads, towns or distribution of agricultural industries, and in this particular example will help illustrate the movement of armies and battle lines during the Great War. The occurrence of coal in the Saarbruck region, in the formations of the oldland, opens up the field of economic geology to which a sketch of this kind aptly lends itself.

d. Wisconsin and New York. In Wisconsin several maps lend themselves nicely to the portrayal of specific areas showing coastal plain cuestas. The Sparta, Tomah, Kendall, and Mauston sheets together show a belt having marked characteristics. Specific information on this region may be gained by reference to the geological map of Wisconsin, and Martin's report on the physical features of the state. Those having access to G-H. Smith's bachelor's thesis in the University of Wisconsin Library on the relation between topography and structure in the Driftless Area will be able to go far toward preparing a useful and interesting drawing, similar to one which is there outlined. The Winnebago

Special sheet of Wisconsin shows distinctly a part of the Niagara cuesta.

The Tug Hill plateau region in the western Adirondacks is equally satisfactory. The Carthage, Lowville, Highmarket and Fort Leyden sheets together represent a well-defined cuesta facing toward the northeast. The geological map of New York State renders assistance in regard to structure.

e. Germany and Sweden. In southeast Germany the cuesta formed by the Swabian Alps comes out beautifully on several of the German maps, scale 1 : 100,000, notably sheets No. 606, 607, 619, 620, 633 and 634.

The cuestas forming the plains of Skane in southern Sweden are very well shown on the Engelholm sheet, No. 8, of the map of Sweden, 1 : 100,000. Two cuestas are present, trending in a northwest-southeast direction. The intermediate lowland in which Engelholm lies is partly submerged under the bay of "Skelder Viken." Both cuestas have a sharp northward-facing scarp and a gentle back slope to the south. The adjacent Finja sheet, No. 9, to the east, shows for a few miles the continuation of the two cuestas, but later they are lost under the heavy cover of glacial drift. The cuestas forming the islands of Öland and Gotland in the Baltic are strikingly represented on the Swedish maps. Most of Öland appears on the Mönsterås, Kalmar, and Ottenby sheets, Nos. 22, 17, and 12 of the Swedish map, 1 : 100,000. Most of Gotland appears on the Visby, Roma, and Hamra sheets, Nos. 39, 31, and 23 of the Swedish map. The island of Öland displays distinctly the steep westward face and the gentle eastward slope of the innermost cuesta. The inner lowland is submerged to form Kalmar Sund. Gotland is apparently made up of several cuestas, none of them of very great length. The drowning of the intermediate lowlands accounts for the small bays at the north and south ends of the island.

EXERCISES

Based upon the Illustrations in Chapter IV

Exercise 1. In Fig. 40, draw ellipses in all of the lozenge-shaped spaces on block *A*; then darken some of the lines similar to the ones already drawn. Transfer the stream forms to block *B* by means of tracing and carbon paper. On block *C* represent freehand a stream similar to the one that has just been drawn. On block *D* draw incorrectly another stream.

Exercise 2. On Fig. 42 add slope lines to produce an effect like that shown in Fig. 44. (Be sure to represent in profile the front and back edges of the block where the stream flows below the surface of the plain.)

Exercise 3. On Fig. 42, draw meander spurs similar to Fig. 46, first as they would appear if the river were flowing toward the observer, and second as they would appear if the river were flowing away from the observer.

Exercise 4. On Fig. 47, complete streams *A*, *B*, and *C* in accordance with method shown in stream *D*. Extend stream *D* two or three meanders toward the observer.

Exercise 5. On Fig. 48, complete stream *A* to resemble stream *B*; complete stream *C* to resemble stream *D*. Add a tributary to stream *B* cut only slightly below the plain, and a tributary to stream *D* cut deeply below the plain.

Exercise 6. On Fig. 50, complete streams *A* and *B* to resemble stream *C*.

Exercise 7. On Fig. 57, determine position of the two vanishing points; then on block *A* represent a series of straight-walled gorges like

those shown on block *B*. Transform the gorges on block *B* into the type shown on block *C* by rounding off the corners.

Exercise 8. On Fig. 58, transform the views shown in *A*, *B*, and *C* into blocks drawn in one-point perspective. In each case allow the front of your block to coincide with the cross-section as shown.

Exercise 9. On Fig. 59, determine the position of the two vanishing points. Change block *C*, by straightening the lines, so that it resembles block *B*. Change block *B* so that it resembles block *C*. On block *D*, draw in carefully, using proper construction lines, a canyon on each of the sides facing away from the observer.

Exercise 10. Transform Fig. 61 into a block diagram in one-point perspective, using the front of the picture for the front of the block.

Exercise 11. Transform part of Fig. 60 into a block diagram drawn in two-point perspective. Remember to keep the two vanishing points on the horizon, which, of course, is the horizon of the picture in the far distance.

Exercise 12. Draw in one-point perspective a simple rectangular block entirely above the observer, so that he sees the under surface.

Exercise 13. Draw a similar block in two-point perspective.

Exercise 14. Draw a rectangular block made up of several layers (like block *A* in Fig. 59), in one-point perspective, with the base just below and the top of the block well above the level of the observer's eye. Then represent one canyon on each of the visible sides, in a manner similar to canyon *n*, block *B*, of Fig. 64.

Exercise 15. Draw in one-point perspective a block similar to Fig. 66, but with the vanishing point to the left instead of the right of the block. Indicate all construction lines.

Exercise 16. Draw in two-point perspective a block similar to Fig. 66. Indicate all construction lines.

Exercise 17. On Fig. 68, indicate where necessary, and label the following: consequent stream, extended consequent stream, subsequent stream, obsequent stream, resequent stream, insequent stream, fall line, inner lowland, outer lowland, cuesta, cuesta face, cuesta backslope, wind gap, beheaded stream, stripped oldland surface.

Exercise 18. Transform Fig. 69, by extending it toward the rear, so that it shows a complete succession of stages, like Fig. 68, leading from the undissected coastal plain at the back to the maturely dissected stage in front.

Exercise 19. On Fig. 72, with colored pencils, tint in the surface areas of the various formations.

(Exercises Based upon U. S. and Foreign Topographic Maps.)

Exercise 20. Refer to geological map of the British Isles and label on Fig. 71 the names of the formations producing the cuestas and lowlands.

Exercise 21. Prepare diagram of combined Sparta, Tomah, Kendall, and Mauston sheets, Wisconsin. Label formations in accordance with the geological map of Wisconsin.

Exercise 22. Prepare block diagram of Winnebago Special sheet, Wisconsin, and label formations in accordance with the geological map of Wisconsin.

Exercise 23. Prepare block diagram of combined Carthage, Lowville, Highmarket, and Port Leyden sheets, New York, and label structural cross-section according to geological map of New York State.

Exercise 24. Prepare block diagram showing cuesta in southeast Germany, using all or parts of sheets No. 606, 607, 619, 620, 633, and 634, of the German map, 1 : 100,000.

Exercise 25. Prepare block diagram of the Lincoln sheet, No. 147, British Ordnance Survey, large sheet series, one-inch map, and label structure in accordance with geological map of the British Isles.

Exercise 26. Prepare block diagram showing the structure of the southern tip of Sweden, using the Engelholm and Finja sheets as a basis for details.

Exercise 27. Prepare block diagram showing structure and topography of the islands of Öland and Gotland and the adjacent coast of Sweden.

CHAPTER V

DOME MOUNTAINS

50. An undissected dome: the block.—The simplest departure from the horizontal strata of plains and plateaus is that produced by slight warping or doming. If the warping is extreme the beds may be sharply turned up on the flanks of the dome; but in many instances, like the Weald of England and the Cincinnati and Nashville domes of the United States, the warping is very gentle. Whether steep or gentle, the same types of features result from erosion.

A block like Fig. 73, *A*, suggests what a dome must look like on the surface of the ground, but it fails to show the internal structure of the dome. In order to reveal this internal structure it is necessary to cut the dome in half and show a fraction of it. Fig. 73, *B*, suggests a good form of block, drawn in one-point perspective. The front of the block gives a good full cross-section of the dome. Another position of the dome is given in Fig. 73, *C*, but this is not quite so useful as Fig. 73, *B*, because the cross-section is distorted, making it less suited to the display of structure in detail. It is also more difficult to draw. If it is desirable that the whole dome be represented, the block may be pulled apart in the middle to reveal the underground structure, as in Fig. 74.

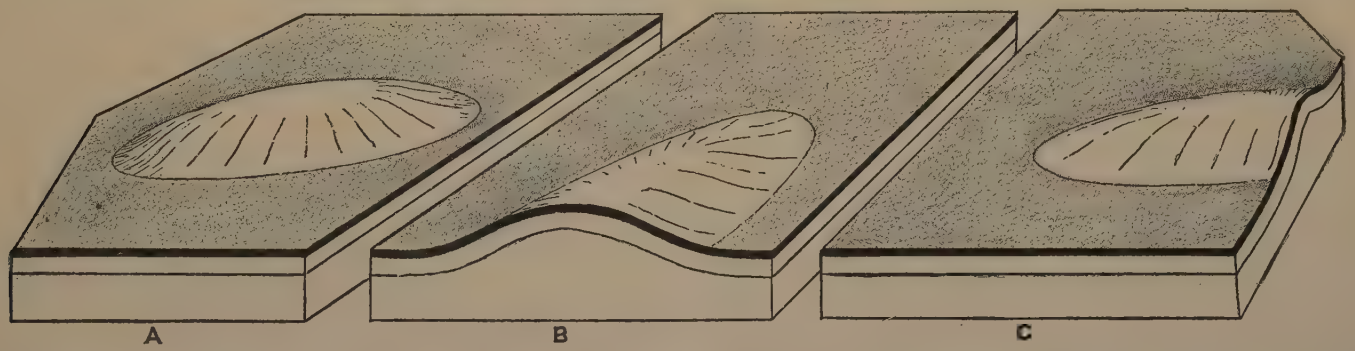


FIG. 73.—Blocks showing undissected domes: *A*, entire; *B*, with undistorted cross-section; *C*, with cross-section at the side. *B* is the most serviceable block.

51. The dome: first stages of dissection.—The initial consequent streams which flow down in a radiating pattern

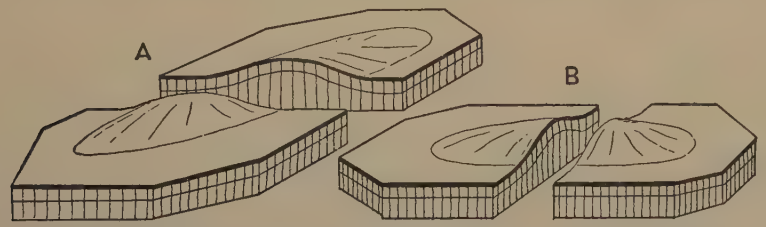


FIG. 74.—Blocks showing undissected domes. Entire domes represented, but separated in the middle to reveal structure.

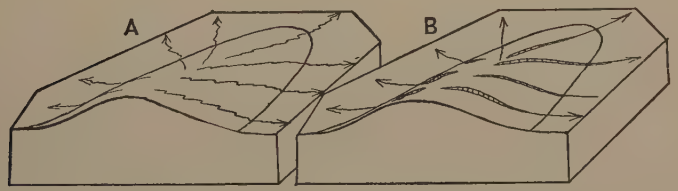


FIG. 75.—Blocks showing the initial drainage of consequent streams on the top of a dome. In *B* the streams are slightly incised.

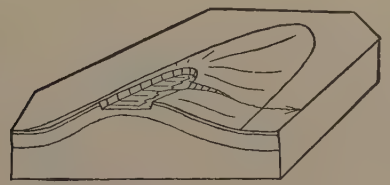


FIG. 76.—A dome after the crest has been breached and a small basin has developed on the axis.

from the center of the dome may be represented as in Fig. 75, *A*, or, after incision, somewhat as in Fig. 75, *B*. The gradual development of a basin or depression at the crest of the dome is one of the most characteristic features of a dome mountain.

It may be represented very simply as if drained by one of the consequent streams, as in Fig. 76. The student may find it convenient to follow some guiding principles which are here offered with the belief that after the effect desired is well in mind, the use of rules will gradually be dispensed with. 1. Lay out, as in Fig. 77, block 1, the horizontal axis *db* and the vertical axis *xy* of the arch. 2. Then (as in 2) draw the ellipse *abc*, representing the base of the dome. 3. Next, on the cross-section, represent the section *mn* of the basin at the crest of the dome. This should be symmetrical with reference to the vertical axis. 4. Dot in the line *ob* representing the axial crest of the elongated dome. 5. Draw the ellipse *mtn*, similar in shape to the larger ellipse *abc*. This represents the rim of

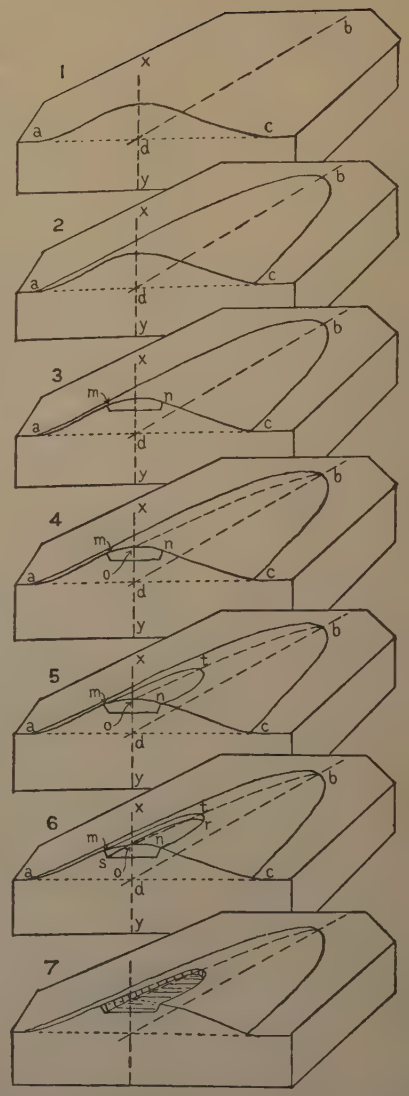


FIG. 77.—Series of drawings to show successive steps in the drawing of a dome. Explained in Section 51.

the basin. 6. Draw the ellipse *sr* below *mtn* to represent the bottom of the basin, stopping it at *r* where it becomes invisible behind the rim *rn*. 7. Complete the drawing by adding the short vertical lines on the walls and the short horizontal lines on the floor of the basin.

single basin is formed, drained in several directions, and in the center of the basin the basement crystalline rocks may be exposed as irregular hills or mountains. As development proceeds the tributaries of the master stream of the region (for example those of stream *m* in Fig. 78), working along the

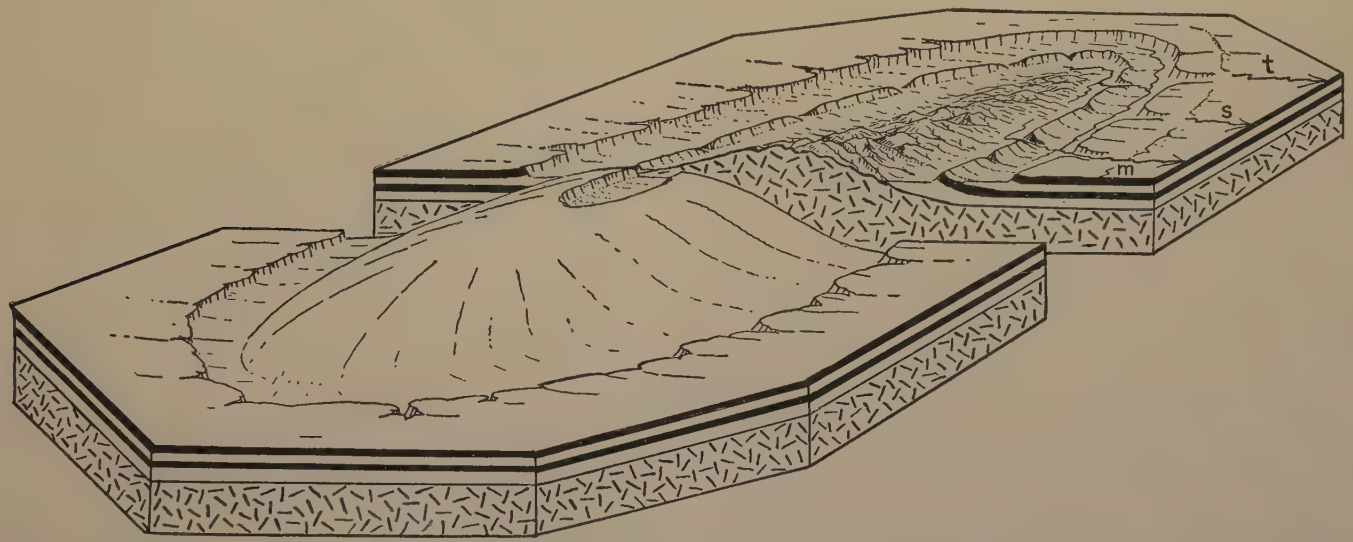


FIG. 78.—Block diagram of dome mountain. The front half is partly eroded, the back part maturely dissected and revealing much of the crystalline core.

52. The dome, maturely dissected.—As the dome is more and more dissected the basin at the top becomes deeper and an increasing number of hard layers is cut through. Each layer forms a rimming ridge or hogback. At first the drainage from the center probably escapes by way of several of the consequent streams. Indeed, each consequent stream may develop a separate basin of its own at the crest. With the gradual enlargement of these separate basins, a large belts of weak rock, are able to advance headward and capture the upper portions of adjacent consequent streams. Thus in Fig. 78 stream *m* has diverted the upper courses of streams *s* and *t*. The drainage thus tends gradually to become annular in pattern as the subsequent tributaries acquire greater and greater length and importance.

It will be noted that, with the advance in development, as the edges of the upper layers retreat farther and farther

from the crest of the dome, these layers assume a plateau character and not the aspect of a narrow hogback ridge. This is brought out in Fig. 78 and is a feature to be seen in many places around the Black Hills.

Figure 79 suggests the use of the block drawn in two-point perspective. The block shown in Fig. 74, *B*, could be treated in the same manner as suggested in Fig. 78.

53. Specific examples: maturely dissected dome, central crystalline core not exposed. *a*. Meeteetse, *b*. Oregon Basin, *c*. Grass Creek Basin sheets, Wyoming.—The Meeteetse sheet displays in clean-cut fashion the essential features of gentle domes eroded at the crest to form basins, but

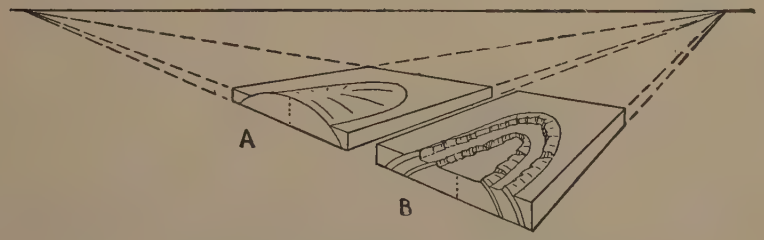


Fig. 79.—Block diagram of dome in two-point perspective.

not revealing any core of crystalline rocks. The representation of this sheet in a very simple manner is suggested in Fig. 80. The block is laid out in such a way that the western edge is directed partly toward the observer, and thus it is possible to show the geological dome structure underlying Spring Creek Basin which is cut in half by the edge of the map. Little Buffalo Basin is developed upon another domal uplift. The somewhat elongated axis of each of these domes trends in a northwest-southeast direction. This is the prevailing trend of many of the domes in the Bighorn Basin. Other examples are to be noted on the Grass Creek Basin sheet. The Grass Creek Basin is enclosed by a series of concentric rimming ridges revealing at least four major resistant formations besides some less important ridge-forming members. Note also on the Grass Creek Basin sheet the remarkably well-shown dome in the southeastern corner of the map. Characteristic triangular hogbacks or "flatirons" may be detected on the northeastern flank where about five ridge-forming members appear to outcrop. The Grass Creek Basin and the Oregon Basin sheets are suggested as problems to be treated in a manner similar to Fig. 80. Additional detail might well be added as the time or inclination of the student or the purpose of the drawing dictates.

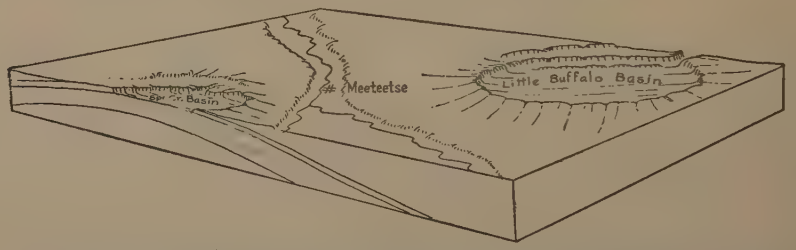


Fig. 80.—Block diagram of Meeteetse sheet, Wyoming, showing maturely dissected domes. The doming is gentle and no crystalline core is exposed to erosion.

In the case of these maps the student is expected to prepare his drawing with reference only to the topographic maps heretofore mentioned. Occasionally reference to geological maps and illustrations is desirable. In this connection Professional Paper 53 on the Geology of the Bighorn Basin will be found helpful.

54. Specific example: maturely dissected dome, central crystalline core not exposed. The Weald, England.—A group of maps may be selected from the British Ordnance

Survey, scale 1 : 63,360, to show the rimming ridges of the Weald, a dome-like uplift. The essential features, with a key to the British maps, are given in Fig. 81. If studied in connection with Geike's Geological Map of England, scale 1 : 633,600, detailed relationships between the geology and the surface features may readily be worked out. The drawing in Fig. 81 lends itself to laboratory use with students in general elementary physiography or geology or to a detailed study of the geology or geography of Europe or the British Isles. The diagram should be used with the maps. The various types of streams, consequent, subsequent, resequent, obsequent, and insequent, may all be recognized in the region. The student may be asked to supply them on the drawing and to explain the relation between towns, roads, and railroads and the physical features.

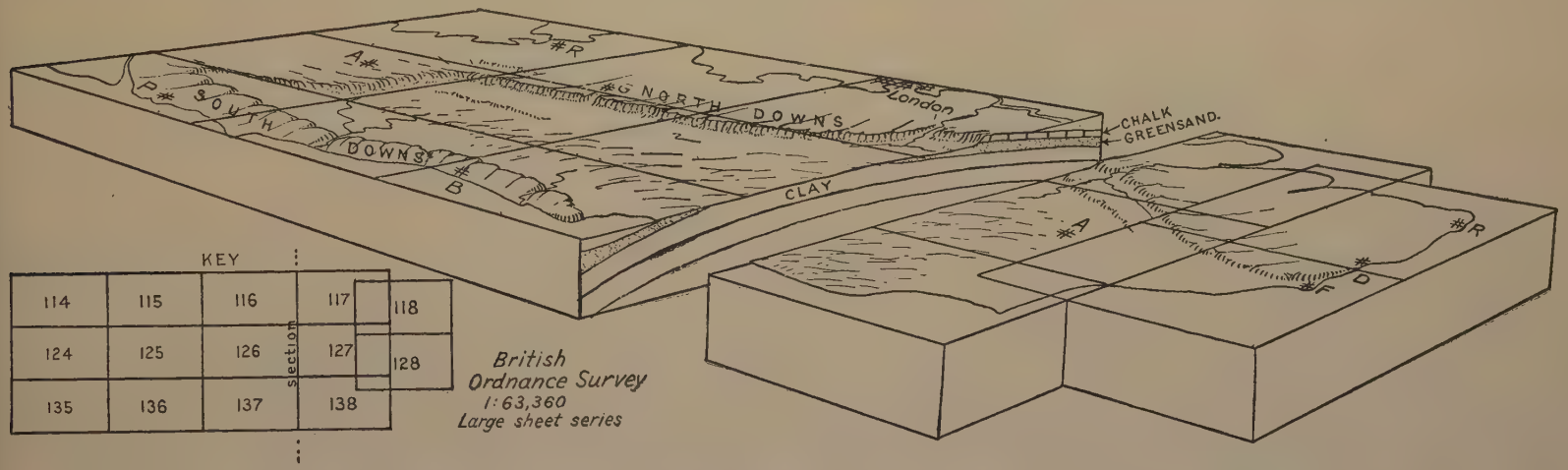


FIG. 81.—Block diagram of the Weald, England. The key indicates the maps of the British Ordnance Survey included in the area.

55. Specific example: maturely dissected dome, central crystalline core exposed. The Black Hills.—Figure 82 is based upon topographic maps and folios, as shown in the key sketch, and upon the cross-sections given in Professional Paper 65, Plate XV, on the geology of the northern half of the Black Hills, and upon the cross-sections given in the 21st Annual Report, U. S. Geological Survey, Plate LXXXVIII, on the geology of the southern half of the Black Hills. The drawing is intended to introduce some devices which may be found applicable to other cases. The entire area in question has been laid out and separated into two blocks along the 44th parallel. The nearer block represents the southern half of the Black Hills with the position of the cross-sections from the 21st Annual Report indicated, but with no details drawn in. The other block was prepared at first in a similar way.

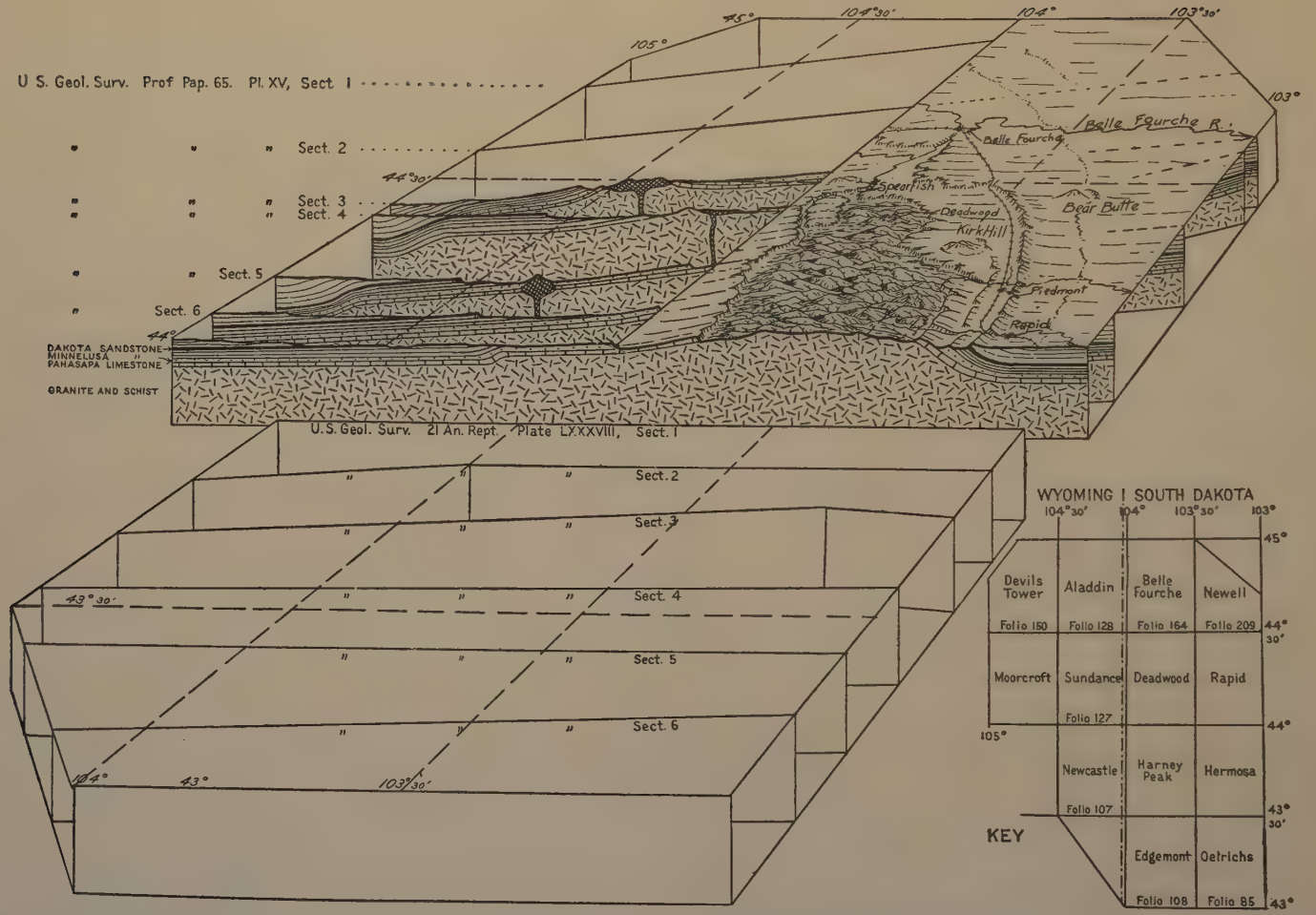


FIG. 82.—Block diagram of Black Hills region based upon cross-sections in Professional Paper 65 and 21st Annual Report of U. S. Geological Survey, as well as upon topographic maps shown in the key. The different portions of the drawing are left in stages of partial completion to show better the relation between the topography and structure.

Then the details of structure taken from the plate in Professional Paper 65 were drawn in on the appropriate cross-sections. Later the topography in the eastern half of the block was supplied from the four topographic maps covering that area. The drawing has been left incomplete in order that the problem of drawing in the cross-sections in the foreground, or of introducing more relief, may be solved by the

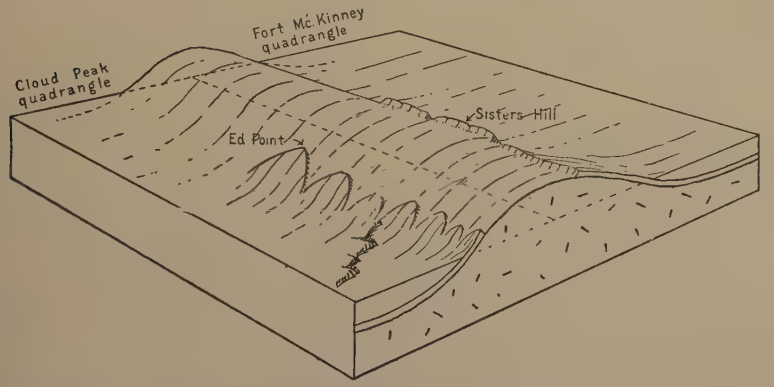


FIG. 83.—A sketchy diagram of region comprised in Fort McKinney and Cloud Peak quadrangles, Wyoming, showing dome structure of the Bighorn Mountains with "flatirons" and hogbacks on the flanks of the range.

student. A drawing of this type helps materially in visualizing a general description of the Black Hills, such as is given in most of the folios mentioned, notably the Devils Tower Folio, No. 150.

56. Specific example: maturely dissected dome, central crystalline core exposed. The Bighorn Mountains.—Two suitable topographic sheets displaying the characteristic features of this area are the Cloud Peak and the Fort McKinney quadrangles, Wyoming. A simple diagram, such as a teacher might draw hurriedly on the blackboard, is given in Fig. 83. No features are accurately represented and all details are omitted. Two features only are indicated, Ed Point and Sisters Hill, because they are deemed worthy of especial note. Ed Point represents the tip of a triangular hogback or "flatiron" on the west flank of the range. Sisters Hill represents an analogous, although a different shaped, feature on the eastern flank, but near the crest of the range.

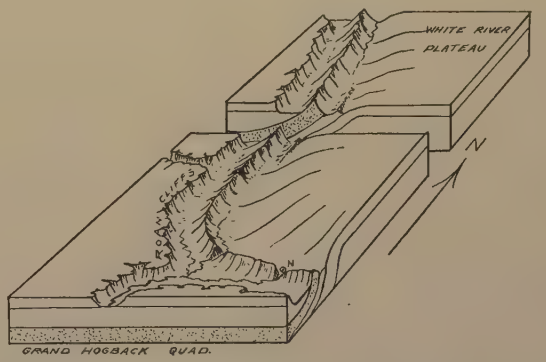


FIG. 84.—Block diagram of Grand Hogback quadrangle, Colorado. Part of a dome on the western flank of the Rockies.

Many other points of interest may be noted in Folio 142. A good problem would be the preparation of a drawing to show in detail the structure and topography of part of this area.

57. Specific example: hogback ridge rimming part of dome. Grand Hogback sheet, Colorado.—The representation of this simple and interesting sheet is given in Fig. 84. Comment upon the area is hardly necessary in view of the previous discussions. In addition to the main hogback, some minor inner ridges are to be detected in the northern half of

the area. When it is possible to prepare a diagram, such as this one, which coincides with the area represented on a single map a marked advantage is to be gained, for thus the student is able to identify more quickly the corresponding parts of each. Reference to U. S. Geological Survey Bulletin 415 will assist further in understanding the features of this region.

58. Other examples of dome mountains.—The Terlingua sheet, Texas, shows a very fine example of an eroded dome in The Solitario, one of the smallest and most regular examples known. On the eastern side it is possible to detect nine or ten ridge-forming beds. Consultation of the geological map of Texas will show that no crystallines are exposed in the center of the uplift.

The Henry Mountains, and the San Rafael sheets, Utah, are also useful in portraying the features of a well-known group of domes. Mt. Ellsworth and Mt. Ellen especially show the concentric hogback ridges. Because of their indistinct aspect as shown on such small-scale and rather generalized reconnaissance contour maps, a block drawing should prove of material assistance to the younger student in clarifying his conception of these somewhat obscure forms. The almost anticlinal or preferably monoclinal warp producing San Rafael swell lends itself admirably to a little sketch.

The Watrous sheet, New Mexico, offers another opportunity in the Turkey Mountain region to portray an eroded dome. Turkey Mountain represents a strong hogback ridge on the northwest flank of the dome. The prominent subsequent valley rimming the dome is utilized by the roadway.

The Danforth Hills sheet, Colorado, shows in the Axial Basin part of a dome whose crest has been eroded.

In addition, a number of sheets representing the eastern base of the Rockies are equally suitable. Of course, they do not show the entire dome, but only a part of the eastern flank. The Livermore and Boulder, Colorado, sheets, the Pikes Peak Special, and the Canyon City, Colorado, sheets, all may be put to service. Other examples along this same belt may be selected by referring to the index sheets of the U. S. Geological Survey topographic maps.

Still further practice in the preparation of drawings showing dome structure and resulting features may be had by consulting the geological maps of Kentucky and Tennessee or the geological map of North America, and combining the information thereon with that derived from the corresponding topographic sheets embodying the region of the Cincinnati and Nashville domes.

EXERCISES

Based upon the Illustrations in Chapter V

Exercise 1. On block *A*, Fig. 73, draw cross-section and remove the front part of the block to show structure of dome.

Exercise 2. Prepare a block similar to *A*, Fig. 74, but showing asymmetrical dome, one side sloping much more steeply than the other.

Exercise 3. On blocks *A*, *B*, and *C* of Fig. 73 represent initial radial pattern of consequent streams, similar to block *B* of Fig. 75.

Exercise 4. Reconstruct blocks *A*, *B*, and *C* of Fig. 73, to show on each block a basin eroded at the crest, following in general the method used in Fig. 77.

Exercise 5. Complete Fig. 78 so that the front block is maturely dissected and resembles the back block.

Exercise 6. On Fig. 78 indicate carefully on the two blocks the position of contour lines, as they might appear if they were actually visible on the ground.

Exercise 7. Using the results of Exercise 6, prepare a contour map of Fig. 78, indicating and labeling on it consequent, obsequent, resequent, subsequent, and insequent streams. Then, with colored pencils, tint the map to show geological outcrops; that is, make a geological map of a dome mountain.

NOTE.—Fig. 78 may be effectively tinted to show geological outcrops as well as the structure.

Exercise 8. On Fig. 80 indicate the geological structure at the end of the block, and color in, on both cross-sections, the geological formations.

Exercise 9. On Fig. 81 tint in very lightly the geological formations at the surface and on the cross-section. Color the water areas on the surface a very light blue. Leave the blank cross-sections without color.

(Exercises Based upon Topographic Maps.)

Exercise 10. Refer to U. S. Geological Survey 21st Annual Report, Plate LXXXVIII, and complete the cross-sections in Fig. 82. Then consult the Edgemont and Oelrichs sheets, South Dakota, and represent the topography of those areas on Fig. 82.

Exercise 11. Prepare a diagram of the Newcastle sheet, Wyoming, making use of the Newcastle Folio, No. 107, U. S. Geological Survey, for structural sections.

Exercise 12. Prepare block diagram of Oregon Basin sheet, Wyoming, using only topographic map as source of information. Use judgment in orienting the block and in representing geological structure.

Exercise 13. Do as in previous exercise for Grass Creek Basin sheet, Wyoming.

Exercise 14. Prepare diagrams of part or all of any of the maps explained in Section 58.

CHAPTER VI

FOLDED MOUNTAINS

59. An undissected fold. Application of the cylinder as the solid form out of which the features of folded mountains are to be carved.—Figure 85 presents two aspects of the cylinder drawn in one-point perspective. It will be noted that in each case the end of the cylinder is represented as an actual circle without distortion. To emphasize the

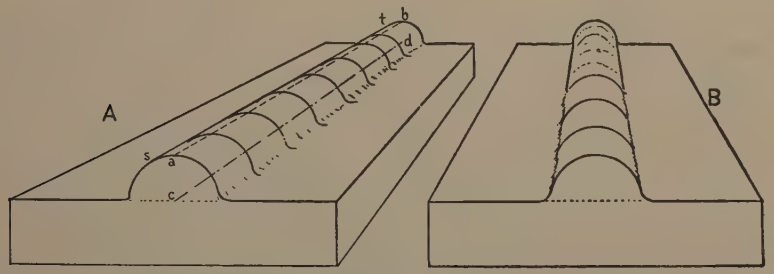


FIG. 85.—Cylinders drawn in one-point perspective. Note that in block *A*, the line *st* is tangent to the circle at each end of the cylinder.

principles of construction, the lines *ab* and *cd* are dotted in on block *A*. The line *ab* represents the crest of the cylinder, and *cd* represents its central axis. The solid line *st* represents the limit of view over the top of the cylinder and is drawn tangent to the circle at each end. An incorrect representation is shown in Fig. 86, where the solid line is drawn along the crest of the cylinder with meaningless results. Fig. 85, *B*, represents the cylinder as seen from above and in front. The base of the arch on each side may be represented by a solid line, as in the background; or the cylindrical shape may be suggested entirely by form lines, as in the fore part of the

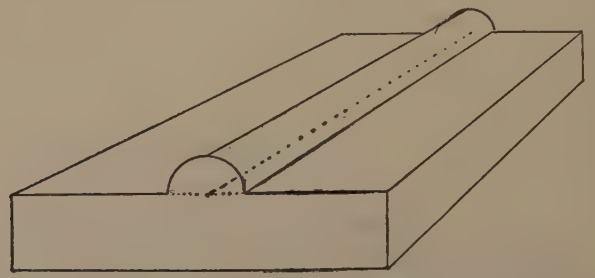


FIG. 86.—Cylinder incorrectly drawn. The top line should be tangent to the circles at each end.

drawing. Still other views are shown in Figs. 87 and 88. Fig. 87 is in one-point perspective; Fig. 88 is in the two-point system. In both of these it will be noted that the front of the cylinder is represented by an ellipse instead of a circle, as in Fig. 85.

Overturned folds are best drawn by representing first the inclined axis of the ellipse at the end of the block, as in Fig. 89. The heavy line *st* at the top is drawn tangent to the ellipse.

These drawings, of course, are rather mechanical and arbitrary in appearance. But unless the student has some

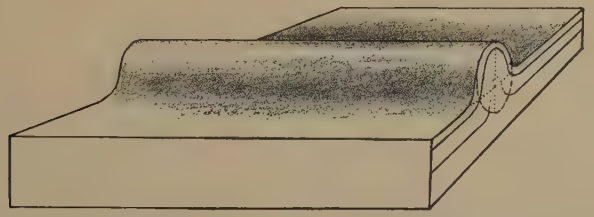


FIG. 87.—Block in one-point perspective and cylinder parallel with the front of the block. The cross-section at the end appears as an ellipse.

forms like these in mind it will be difficult for him to represent the variety of features found in nature.

60. Stages in the erosion of an anticline.—Figure 90 represents four stages in the erosion of an anticline. It will

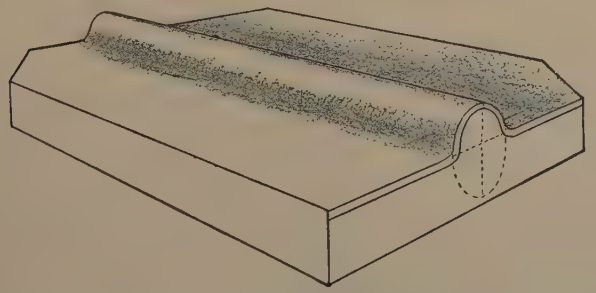


FIG. 88.—Block in two-point perspective and cylinder parallel with one face of the block. The end appears as an ellipse.

be noted that the features are, in a way, quite suggestive of those developed on a dome. Fig. 90, *A*, represents the initial stage. *B* shows the appearance after the crest has been worn off to form a basin, and *C* shows the later stage where the original anticlinal mountain has given place to an anticlinal valley, flanked by two monoclinal ridges. A later stage is shown in *D*, where the monoclinal ridges have been still further pushed back. As this process continues and the anticlinal valley becomes lower, the bottoms of the synclinal troughs on each side come to have altitudes higher than the axis of the anticline, thus becoming synclinal or flat-topped mountains.

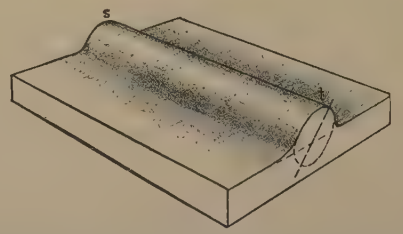


FIG. 89.—Elliptical cylinder with oblique axis slanting toward the observer, to show the solid form from which the features of overturned folds may be developed.

The actual drawing of these features ought to give the teacher or student no difficulty if he endeavors simply to modify the original cylinder. For instance, section *D* in Fig. 90 may be produced by drawing the complete cylinder first, then indicating the portion of the cylinder to be removed. This procedure is especially applicable when drawings are placed on the blackboard. Draw lightly in chalk the crude undissected form. Then remove that part which is not wanted. That is to say, remove the part which erosion has stripped away.

61. Representation of successive stages in the erosion of a series of parallel symmetrical folds.—Figure 91 represents in a very arbitrary and mechanical manner a series of

folds showing in successive stages the features developed by erosion. The drawing is in one-point perspective. At first all the folds were drawn, and then construction lines were ruled off to indicate how much of the fold in the various parts of the drawing was to be eliminated. This is better practice than to try to draw in the features without considering the folds from which they were derived.

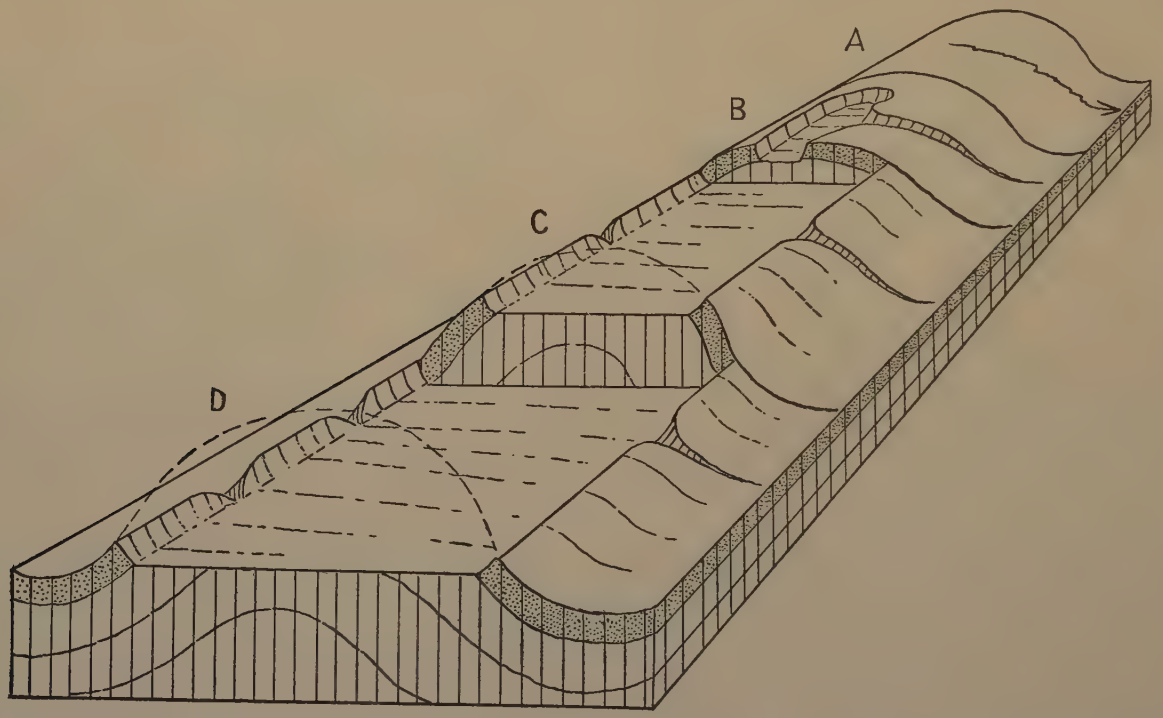


FIG. 90.—Block showing successive stages in the erosion of an anticline

Fold 1 shows three streams, *X*, *Y*, and *Z*, lateral consequent streams tributary to the main longitudinal consequent, *C*. Stream *Z* has already opened out a valley on the crest of the anticline. In fold 2 all the tributaries have developed valleys along the anticlinal axis. In fold 3 tributary *Z* has gained an advantage over *Y* by headward erosion and has diverted its waters. In fold 4 this same process of diversion has been carried still further. Some tributary further downstream than *Z* has captured all the tributaries upstream, and

the union of all these tributaries has formed stream *S*, a subsequent stream. Fold 5 shows that stream *S*, working upon soft formations, has gained an advantage over stream *C*, and by the work of its obsequent tributaries *O* has broken stream *C* into a number of segments, now tributary to *S*. Fold 6 shows *S* discovering a hard, underlying formation over which it found itself superposed, and in fold 7 a resequent tributary, *R*, is being developed. Thus this illustration shows the transformation of an anticlinal ridge into an anticlinal valley, bordered by monoclinal ridges, and, similarly, it shows a synclinal valley transformed into a synclinal mountain, bordered by monoclinal valleys.

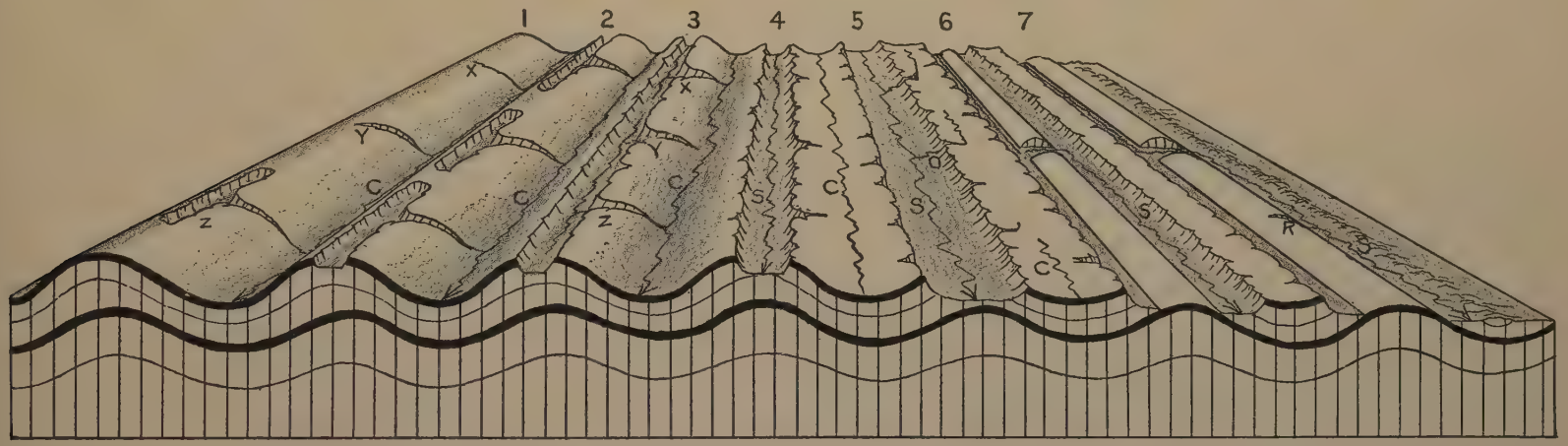


FIG. 91.—Series of folds showing successive stages in the erosion of anticlines and synclines. Explained under Section 61.

62. Pitching anticline, the essential features.—The essential features produced by the erosion of a pitching anticline are shown in Fig. 92. It will be noted that there are two monoclinal ridges like those previously illustrated, but, instead of remaining parallel with each other, they converge in the direction toward which the anticline is pitching. The steep face of each monoclinal ridge is directed toward the axis of the anticline. The slope away from the axis is gentler. So, too, the nose formed by the junction of the two converging ridges tapers off gradually in harmony with the pitch of the fold.

63. Pitching syncline, the essential features.—The corresponding features of an eroded syncline are shown in Fig. 93, together with those of two adjacent anticlines, all pitching in the same direction. In the case of the syncline it will be noted that the two monoclinal ridges converge in a direction away from the pitch of the fold; the nose of the syncline is blunt and does not taper off gradually like the nose of an anticline; the converging ridges have their gentle slopes directed toward the axis

of the syncline, the steep slopes being on the outside of the syncline.

64. Pitching folds, simple method of expressing the features of zigzag ridges.—The representation of these features is accomplished with the greatest ease, by means of very few strokes, by following the steps shown in Fig. 94. Draw first the crests of the converging ridges (*A*). Then, as in *B*, show the profile of the nose. Follow this up (*C*) with a few

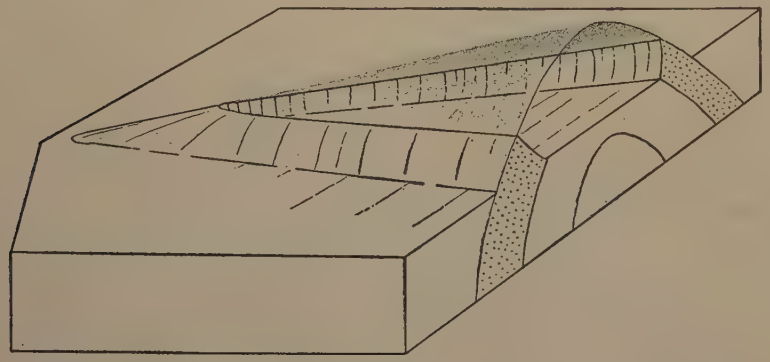


FIG. 92.—Block drawing to show features developed by erosion of a pitching anticline.

form lines on the gently sloping side of the ridge to suggest the dip of the bed. Next (*D*) indicate the steep side of the ridge by short, hachure-like form lines. Finally (*E*) a few almost horizontal strokes will suggest the flat floor developed along the axis of the fold between the ridges. Fig. 94, *F*, shows the form of the anticline if it does not pitch very steeply and if a considerable portion of the nose has survived erosion.

65. Pitching folds, features produced by two or more ridge-forming members.—Figure 95, *A* and *B*, represents the features developed upon an anticline made up of several hard members. The pitch is away from the observer. Such a drawing is readily prepared in a manner similar to that just described and illustrated in Fig. 94. Fig. 95, *C* and *D*, illustrates the features produced upon a syncline made up of several hard members, the pitch in this case being toward

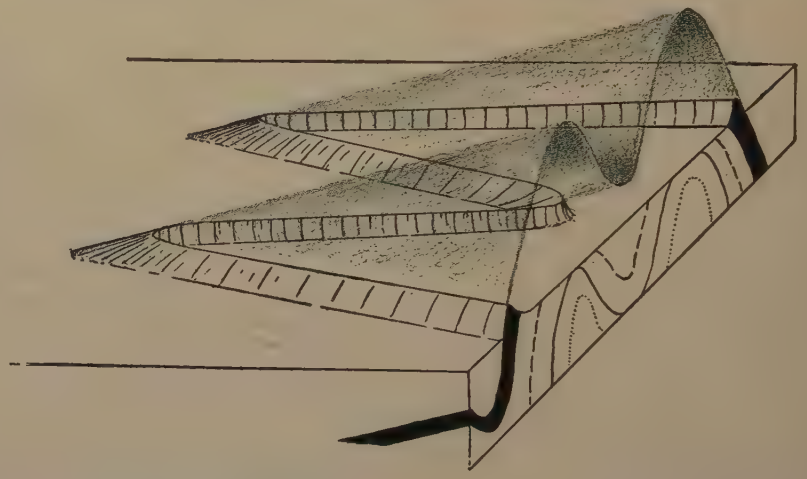


FIG. 93.—Block drawing to show features developed by erosion of two pitching anticlines and syncline between them.

the observer. Figure 95 is introduced to present a good type of figure for book illustration, because of its compactness, whereas Fig. 94 is more suitable for blackboard use owing to the ease and speed with which it may be prepared.

The parts of Fig. 95 are so drawn as to invite comparison between anticlines and synclines on the one hand, and, on the other hand, between synclines among themselves, and anticlines among themselves, depending upon the presence or absence of axial ridges. As previously suggested, oppor-

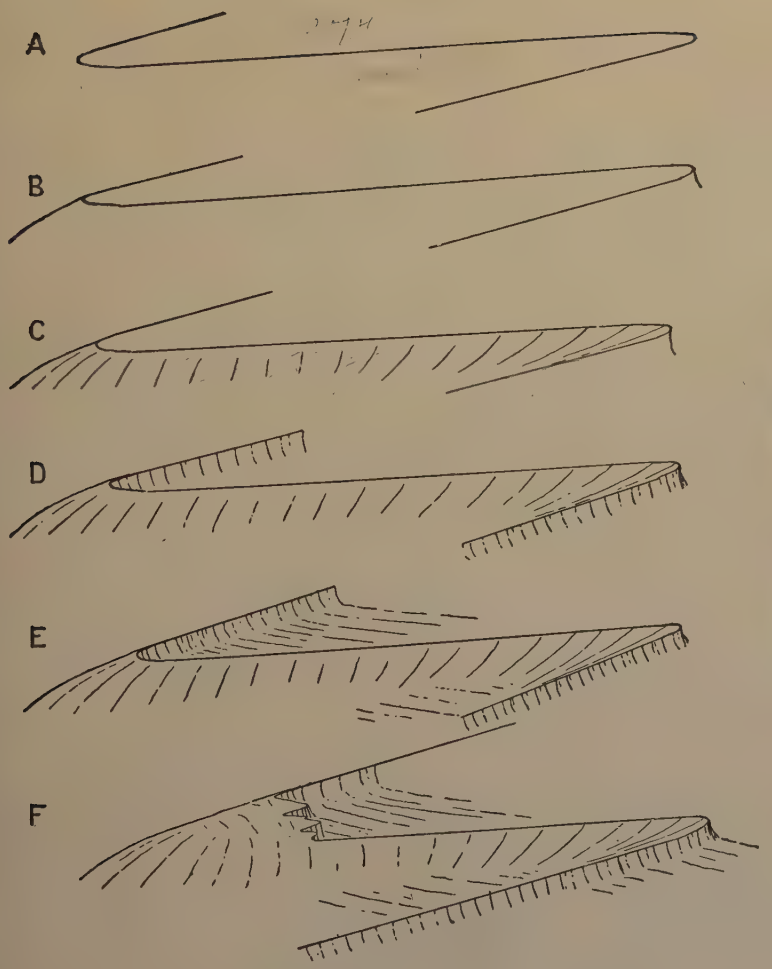


FIG. 94.—Simple method of drawing an eroded pitching anticline and syncline, showing the different steps in preparing the drawing. Sketch *F* is a slight modification of sketch *E* and shows the appearance when the nose of the anticline is not so much reduced.

tunities for comparison should not be neglected. Throughout this text it has been deemed just as important to consider the larger aspects of block-diagram presentation and use, such as general lay-out, the ideas to be expressed, and the purpose for which the diagram is intended, as to consider the detailed matters having to do with the representation of small features. As a matter of fact, the representation of the smaller details may be accomplished in a variety of ways,

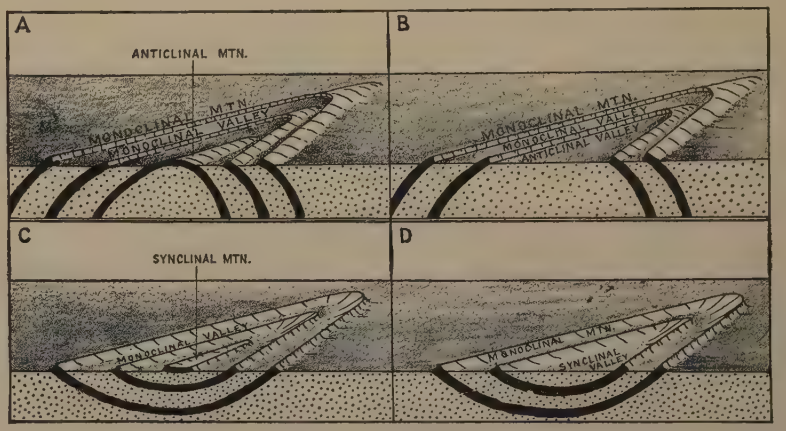


FIG. 95.—Diagrams to show features developed upon pitching anticlines and synclines.

by shading, by lines, by color, depending somewhat upon the personality of the worker, but the general lay-out of the drawing is much more vital and is guided by more definite rules.

The drawing of pitching folds in two-point perspective is shown in Fig. 96. The upper block *A*, indicates the construction lines necessary to a proper and pleasing orientation

of the folds. The lower block, *B*, represents the features developed by erosion.

66. Specific example: monoclinal ridges. Eagle Rock quadrangle, Virginia.—Figure 97 represents in two-point perspective part of the Eagle Rock sheet. Comparison with the map will enable the reader to identify most of the features and to understand the structure more fully. The preparation of the diagram was aided by a study of the Geological Map of Virginia, for one would hardly be justified, in this case, in interpreting the structure from the topographic map alone. The teacher will find this map useful in many ways, notable in showing the occurrence of numerous sinks in the limestone region of the southeast.

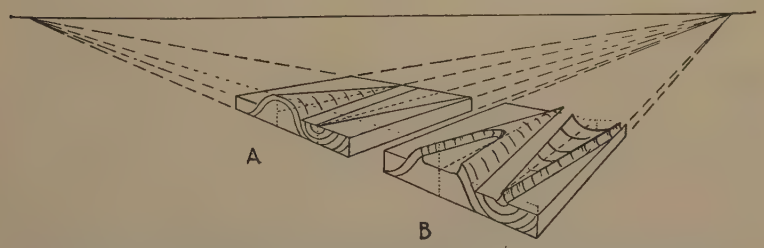


FIG. 96.—Pitching anticline and syncline, drawn in two-point perspective, showing in block *A*, the solid form from which the features of block *B*, are carved.

67. Specific example: pitching anticlines and synclines, monoclinal ridges. Everett quadrangle, Pennsylvania; Hollidaysburg quadrangle, Pennsylvania.—The features of the Everett region are expressed in a purely diagrammatic fashion in Fig. 98, which coincides with the limits of the quadrangle and is drawn in one-point perspective. This gives a good cross-section at the southern end of the block, showing the anticlinal structure prevailing in the western half of the map. The eastern side of the block presents a cross-section of the synclinal basin, pitching toward the northeast. Of especial interest is the Warrior Ridge anticline, pitching southward, and a similar feature near the western edge of the map. The distinct platform fronting Tussey Mountain, as well as Evitts and Dunning Mountains, is worthy of note, and indeed many other features deserve mention and study.

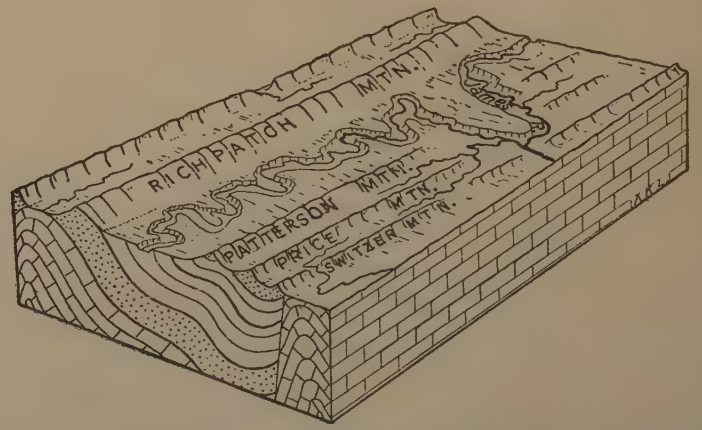


FIG. 97.—Block diagram of part of Eagle Rock quadrangle, Virginia. Richpatch Mtn., Price Mtn., and Switzer Mtn., are monoclinal ridges. Patterson Mtn. is a synclinal ridge.

Figure 99 presents in a somewhat different style the salient features of the Altoona region, in the Hollidaysburg quadrangle, Pennsylvania. This is a cruder sort of diagram, but it is easily drawn and is especially adaptable to blackboard illustration. It does not require the laying out of the block in perspective, but, on the other hand, it does not connect the map quite so clearly with the drawing, because the limits of the two are not identical.

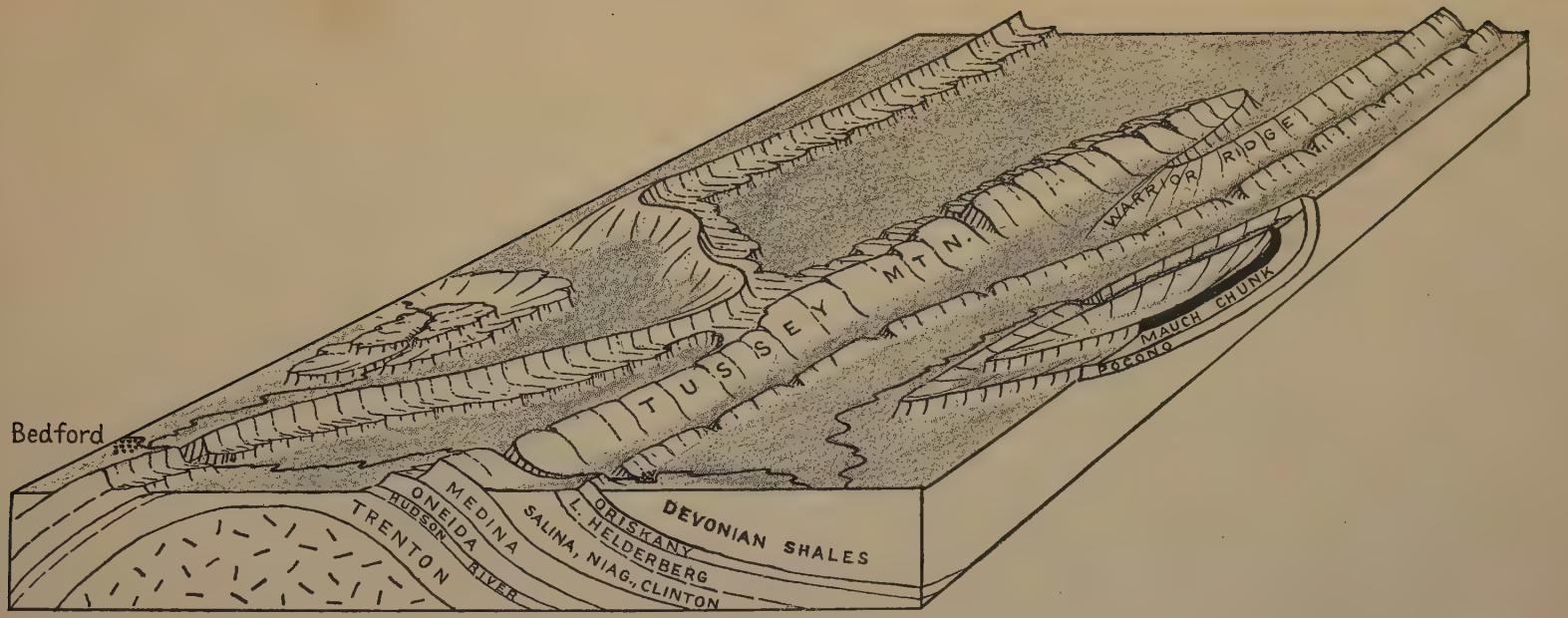


FIG. 98.—Block diagram in one-point perspective of Everett quadrangle, Pennsylvania, showing zigzag ridges and pitching anticlines and synclines.

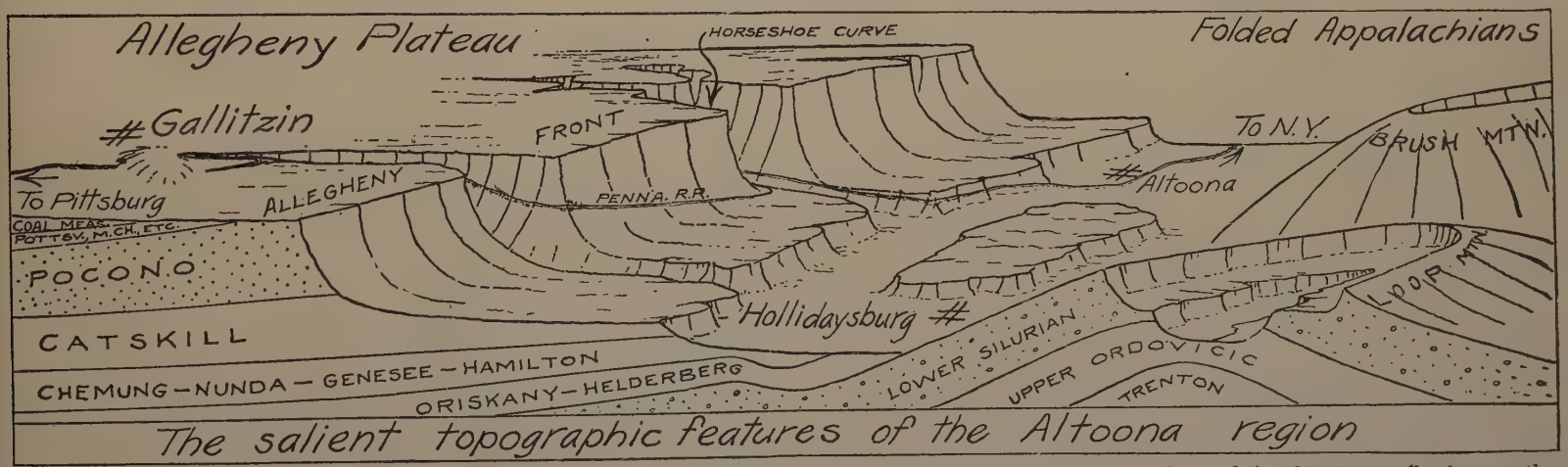


FIG. 99.—Diagrammatic representation of the salient features of part of the Hollidaysburg quadrangle, near Altoona, Pennsylvania. The front of the drawing gives the geological cross-section of the region. This sketchy representation is easier to make and is almost as effective as the block drawing such as used in Fig. 98. (Permission of N. Y. Academy of Sciences.)

68. Specific example: monoclinal ridges and pitching syncline. Harlan and Nolansburg quadrangles, Kentucky.—The representation of these two maps is neatly and effectively shown in Fig. 100. A drawing of this character is probably as satisfactory as any type which can be prepared to illustrate the features and structure of a topographic map. If each topographic map published could be accompanied with

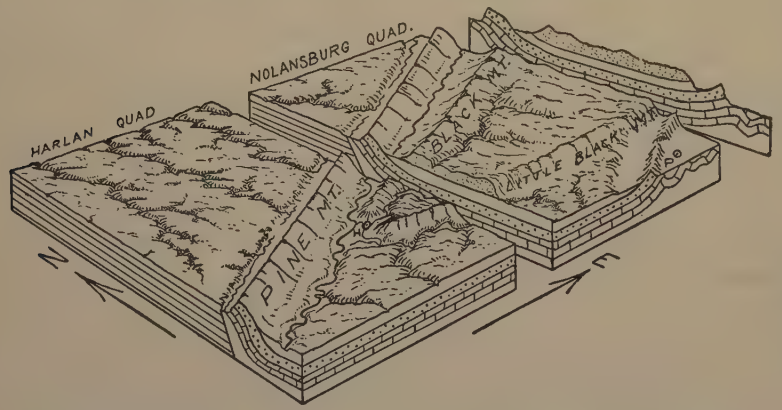


FIG. 100.—Block diagram giving the structure and topography of the Harlan and Nolansburg quadrangles, Kentucky, showing syncline pitching very gently toward the east. Cumberland Plateau represented in the northwest. Note particularly the use of the cross-section at the far end of the drawing to show structure on the side of the block which is turned away from the observer.

a sketch of this kind, and perhaps also a few paragraphs of description, it would have a much clearer meaning to all and a correspondingly wider use. One innovation in Fig. 100 is the introduction of an additional cross-section at the far end of the drawing. This represents what might be the side of the next adjacent block to the east, but the topography beyond is omitted.

69. Specific example: pitching syncline. Harrisburg and New Bloomfield quadrangles, Pennsylvania.—Figure 101 utilizes a slightly different technique, representing in a very simple manner the structure and topography of the region around Harrisburg. This diagram has already proved of especial value in teaching purposes because of its clearness and simplicity. Having in mind the essential forms to be set before the student, the teacher pays little regard to rules of perspective, because the sides of the block are not introduced into the drawing. In its preparation reference to the Pennsylvania State Geological Map and study in the field made it possible to indicate rather accurately the geological formations which control the topography.

70. Specific example: monoclinal ridges. Delaware Water Gap sheet, New Jersey-Pennsylvania.—Little comment is needed upon Fig. 102, intended to show the structure and topography of the Delaware Water Gap region. The topographic map with the description of the region printed on the back furnishes all the necessary data.

71. Specific example: complete synclinal or canoe-shaped valley. The Wyoming Basin, Pennsylvania.—As a final example, Fig. 103 is introduced to show a rather extensive area nvolving a number of topographic maps, notably the Scranton, Pittston, Wilkes-Barre, and Shickshinny Pennsylvania, sheets. Here the topographic forms are probably represented in a more diagrammatic and generalized fashion than in most of the drawings presented. This is deemed especially desirable where the introduction of irrelevant details of erosion, so numerous in this area, would confuse the main ideas which are to be expressed.

72. Other examples of folded mountains.—The zigzag ridges of eastern Pennsylvania present the best problem

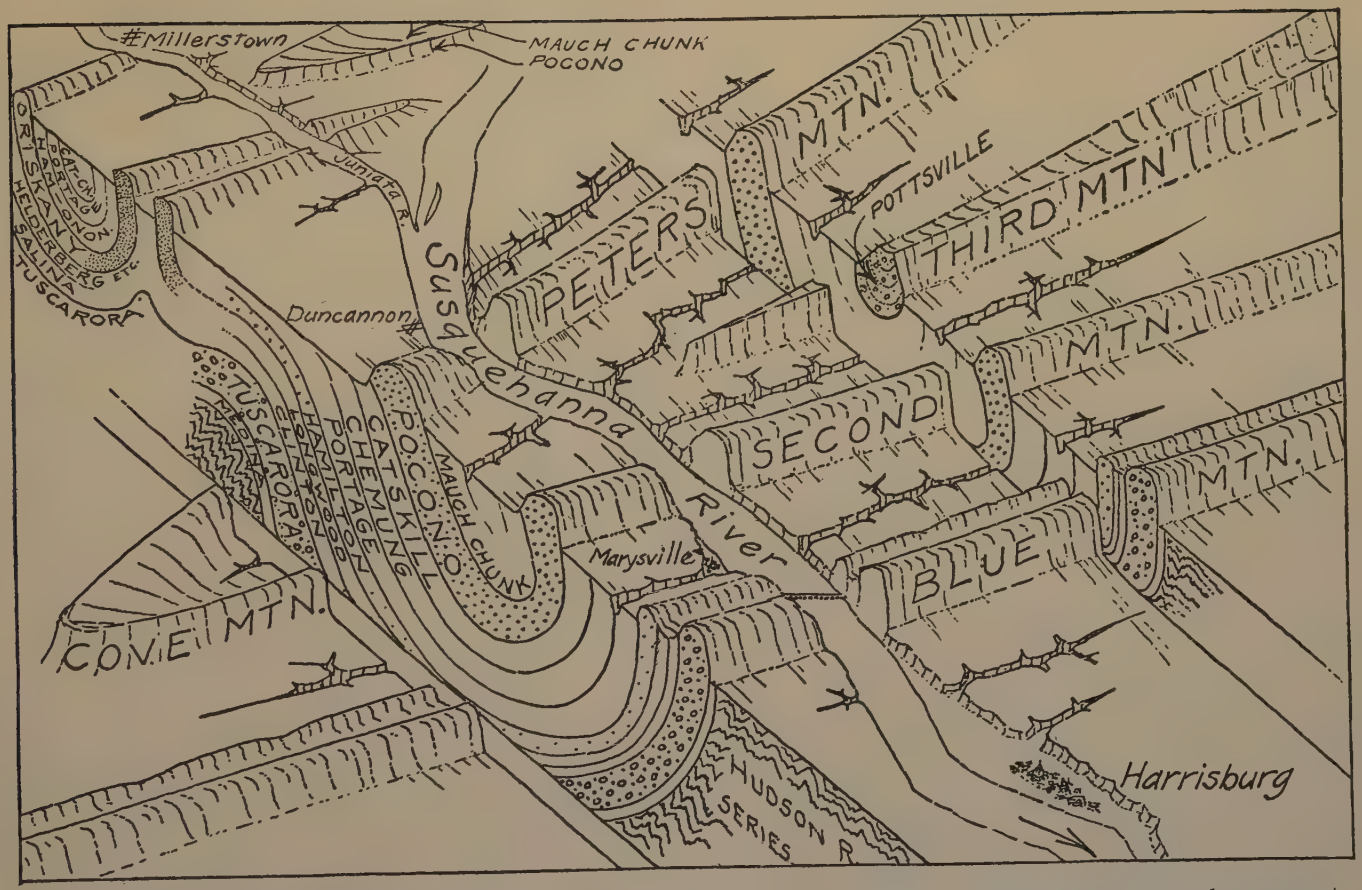


FIG. 101.—Diagrammatic representation of the relief features of the Harrisburg and New Bloomfield quadrangles, Pennsylvania. A northeastward pitching syncline is easily recognized. It is slightly overturned and involves four ridge-forming members. The transverse course of the Susquehanna River across the ridges, and the subsequent tributaries are strongly brought out. The Cretaceous peneplane remnants on the ridge crests, the Tertiary peneplane as developed on the broad valley floors, and the post-Tertiary dissection by the streams constitute the salient elements of the topography. (Permission of N. Y. Academy of Sciences.)

that could be devised for the student who wishes to test his ingenuity in preparing a valuable and instructive diagram. The area comprised in the following sheets is especially recommended: Sunbury, Shamokin, Catawissa, Mahanoy, Millerstown, Millersburg, Lykens, Pinegrove, Pottsville, New Bloomfield, Harrisburg, Hummelstown, Lebanon, and

FIG. 102.—Simple diagrammatic representation of the Delaware Water Gap sheet, showing structure and topography. The Cretaceous peneplane is preserved on the hard, resistant Shawangunk conglomerate which forms Kittatinny Mountain, and on the pre-Cambrian crystallines which form the New Jersey Highlands at the eastern edge of the drawing. The Tertiary peneplane on the floors of the valleys and the post-Tertiary stream dissection are distinctly indicated. A hasty sketch intended to bring out the salient facts of the geology and topography. (Permission of N. Y. Academy of Sciences.)

Wernersville. These maps may all be mounted in one large sheet for wall use, thus bringing out more clearly the continuity of the ridges than if all the sheets are handled separately. It is suggested that the student devise one diagram which will show the topography and geological structure of this whole area. To do this it will be necessary to study the situation and decide where structural cross-sections will be placed to best advantage. This means that the sections should distinctly show the structure, but at the same time should not break up the drawing so much as to spoil its value. Of course the student should have access to the geological map of Pennsylvania, though even without this he should be able to interpret the larger aspects of the structure.

Another choice sheet is the Fort Payne quadrangle of Alabama and Georgia. The structure here may be interpreted from the map, or use may be made of the Geological Map of Alabama and the Stevenson Folio, which covers the

FIG. 103.—Diagrammatic representation of the principal elements of the Wyoming or northern anthracite coal basin. Owing to its synclinal structure the coal-bearing formations were here preserved from erosion. The letters refer to the following cities: *S*, Scranton; *P*, Pittston; *W*, Wilkes-Barre; *N*, Nanticoke. (Permission of N. Y. Academy of Sciences.)

adjacent quadrangle to the north. The Chattanooga sheet, in Tennessee, is just as satisfactory, and this area is covered by a folio. In each of these regions the most instructive feature is a well-marked anticlinal valley. Wills Valley in the Fort Payne region has a structure similar to that of Sequatchie Valley in the Chattanooga region though it is not a continuation of the same feature.

The Little Rock quadrangle, Arkansas, in the Ouachita Mountains region presents additional significant features of

folded mountains. The map is noteworthy as an example of synclinal structure, involving perhaps six or seven ridge-forming members. A part of this structure, that due to the uppermost members, is illustrated by a block diagram on the back of the sheet in the edition of 1918, describing the Camp Pike locality. The syncline pitches to the west, but in the very northwest corner of the map the axis swings around so as to have a northwest trend. Accompanying the syncline is an anticline, the axis of which is almost identical with the northern edge of the map.

The Greenland Gap quadrangle in West Virginia reveals, perhaps better than any other topographic map yet published in the United States, the structure of a folded region. The anticlinal character of New Creek Mountain is splendidly represented by the expression of the contours in Greenland, Cosner, and Kline Gaps. Knobly Mountain is a monocline, dipping eastward, the dip being distinctly represented by the contours in Robinson Gap, Real Gap, and at Falls just east of Greenland Gap. The formation responsible for Knobly Mountain is, of course, higher stratigraphically than the one producing New Creek Mountain. Walker Ridge would be interpreted from the map as a monocline dipping west. It results from the same formation as Knobly Mountain. Fore Knobs and Allegheny Front are due to still higher members lying almost horizontally, with possibly a slight dip westward.

Some of the French maps in the Jura region may be used with satisfactory results. The hachure maps on a scale of 1 : 80,000 are not quite so readily interpreted as the U. S. Geological Survey topographic contour maps; the 1: 200,000 maps of the same area are on slightly too small a scale, but, nevertheless, if studied with the geological map of France, or, better, the geological sheets, 1 : 80,000, will be found to show interesting structural details which may be presented in block-diagram form. For instance, sheet No. 42, scale 1 : 200,000, can be interpreted with the help of the geological map of France. Just northeast of Les Planches (in south central part of the map, and 10 kil. north of its southern margin) is a syncline pitching toward the northeast. The blunt nose of the syncline, 2 kil. southeast of Les Chalèmes, is well shown by the contours. In the 1 : 80,000 map, the Ornans sheet, No. 127, will be found suitable as an introduction. This with the adjacent sheets, No. 138 and No. 139 on the same scale, covers most of the French Jura.

The topographic maps of Switzerland, scale 1 : 25,000, showing rock outcrops by means of hachures in addition to the contours (contour interval 10 meters), express, probably better than any other topographic maps issued, the underground structure which controls the surface forms. A few examples of maps from the Swiss Jura may be pointed out, but there are many others equally good, or even better than some of these. The student would usually not care to represent an entire sheet, with its wealth of detail, in block-diagram form. Small portions of different sheets might better be selected for such treatment. On the Court sheet, No. 108, the Birse River cuts through an anticlinal ridge, north of Court, in a gap, the Gorges de Court, which very much resembles Greenland Gap, West Virginia, above mentioned. The anticlinal structure is perfectly represented, and four or five resistant rock members, producing cliffs in the gorge, are distinguished. This map, with the Gänsbrunnen sheet, No. 109, shows the entire gap. The gently pitching nose of the anticline in the region of Champoz appears on the Court

sheet. On the Gänsbrunnen sheet the same anticline is again breached by the Raus River, but only one hard cliff-forming member appears in this gap.

On the Undervelier sheet, No. 103, of the Swiss map, 1 : 25,000, south of Undervelier is represented a double anticline trenched in the southern part of the area by the Sorne River. The two anticlines, with the intermediate syncline, are very clearly shown by the hachures which indicate the rock outcrops. Just north of Undervelier another small anticline is breached by the same river, and still farther north the Sorne River cuts through a large monoclinal ridge, dipping north. The eastward continuation of the monoclinal structure is clearly shown on the Soulce sheet No. 106. The Moutier sheet, No. 107, shows two anticlines cut through by the Birse River, one at Choindez, the other northeast of Moutier. Between these two anticlines a distinct syncline is shown, part of which forms the Côte du Droit. The Sonceboz and Pieterlen sheets, Nos. 119 and 122, together show a remarkably well represented anticline, breached by the Suze River at Rondchatel.

The topographic map of former Austria-Hungary, on a scale of 1 : 75,000, portrays folded structure in the Istrian peninsula and the Dalmatian Islands. The Sesana und St. Peter sheet, No. 5752 (Zone 23, Column X), represents an entire anticline or dome. The irregular topography occupying the central part of the map is developed upon the underlying sandstones and shales. The surrounding area is limestone, dipping away in all directions from the dome. The escarpment at the east of the dome is well shown. Along the southern side of the dome the streams from the shale area go underground upon reaching the limestone, in a number of circular basins rimmed by limestone cliffs.

EXERCISES

Based upon the Illustrations in Chapter VI

Exercise 1. On Fig. 87 place a cross-section through the middle of the cylinder parallel to the end of the block, removing enough of the block to make a good structural section visible.

Exercise 2. Do the same on Fig. 88.

Exercise 3. Do the same on Fig. 89.

Exercise 4. Draw a block similar to Fig. 89 but with the axis of the ellipse sloping away from the observer instead of toward him.

Exercise 5. Modify Fig. 90 so that section *A* resembles section *B*, section *B* resembles section *C*, and section *C* resembles section *D*. Change section *D* so that the anticlinal valley is lower than the axes of the synclines on either side.

Exercise 6. On Fig. 91 label the following features: lateral consequent stream, longitudinal consequent stream, subsequent stream, obsequent stream, resequent stream, anticlinal mountain, anticlinal valley, synclinal valley, synclinal mountain, monoclinal valley, monoclinal mountain.

Exercise 7. Prepare a block resembling Fig. 92 but in two-point perspective, with the axis of the anticline directed toward one of the vanishing points.

Exercise 8. Prepare a contour map of the eroded nose of a pitching anticline like Fig. 92. Prepare a hachure map of the same. On each one, color in the geological formations and indicate the direction of dip of the strata in several places, and also the pitch of the fold.

Exercise 9. Prepare a block, similar to Fig. 93, but in two-point perspective.

NOTE.—Draw construction lines representing the axis of the folds toward one of the vanishing points.

Exercise 10. Prepare a contour map of the features shown in Fig. 93. Be careful to bring out the steep and gentle slopes of the ridges. Prepare a hachure map of the same. On each one, tint in the geology and indicate the dip of the formations and the pitch of the folds.

Exercise 11. Using the zigzag line shown in *A*, Fig. 94, represent an anticline and syncline pitching to the right instead of to the left, as has been done in the rest of the drawing.

Exercise 12. Combine the features shown in Fig. 95, *A* and *C*, in one drawing, joining the ridges so as to produce the usual zigzags.

NOTE.—The pitch of both the anticline and the syncline must be in the same direction.

Exercise 13. Redraw both blocks of Fig. 96 so that the folds pitch toward the other vanishing point.

Exercise 14. On Fig. 97, color the surfaces where sink holes might be expected, using a pale blue tint. Then examine the topographic map for such features.

Exercise 15. Draw an east-west cross-section on Fig. 98 through the letter " D " of " Warrior Ridge," and label the formations by name.

Exercise 16. On Fig. 98, label an anticlinal mountain, an anticlinal valley, a synclinal mountain, a synclinal valley, a monoclinal mountain, and a monoclinal valley.

Exercise 17. On Fig. 99, on the cross-section, color in strongly the geological formations. Then, using the same colors, tint in lightly the outcrops of the same formations on the landscape, judging their extent by the topography.

Exercise 18. On Fig. 100 color cross-sections and surface features as suggested in Exercise 17.

Exercise 19. On Fig. 101 indicate on the two cross-sections the axial plane of the syncline and show that it dips slightly to the southeast. Color in the cross-sections and surface features as in the two previous exercises.

(Exercises Based upon Topographic Maps)

Exercise 20. Prepare a comprehensive block diagram of the folded region of eastern Pennsylvania represented on the topographic sheets listed in Section 72 of the text. The diagram may be separated into as many parts as necessary to introduce the desirable cross-sections.

Exercise 21. Prepare a block diagram of the Fort Payne quadrangle, Alabama.

Exercise 22. Prepare a block diagram of the Chattanooga sheet, Tennessee.

Exercise 23. Prepare a block diagram showing structure and topography of the western half of the Greenland Gap sheet, West Virginia. Then on a much larger scale show the features at Greenland Gap and indicate on the drawing the position of the contour lines. Draw several cross-sections from northwest corner of quadrangle to the southeast corner, giving all possible interpretations for structure of Patterson Creek Mountain. Which interpretation appears most likely?

Exercise 24. Prepare a block diagram showing the structure and topography of the Sonceboz and Pieterlen sheets, Nos. 119 and 122, map of Switzerland 1 : 25,000.

Exercise 25. Show on a block diagram the structure and topography of the eastern half of the Undervelier sheet, No. 103, map of Switzerland 1 : 25,000.

Exercise 26. Show in block-diagram form the structure and topography of western half of the Moutier sheet, No. 107, map of Switzerland 1 : 25,000.

Exercise 27. Represent on a block diagram the Sesana und St. Peter sheet, No. 5752 (Zone 23, Col. X) of the map of Austria, 1 : 75,000.

Exercise 28. Study the Pago sheet, No. 6254 (Zone 28, Col. XII), map of Austria 1 : 75,000, and work out the possible structure of this region. Note that most of the ridges are synclinal and that most of the bays are drowned anticlinal valleys.

CHAPTER VII

BLOCK MOUNTAINS

73. The undissected block in various positions.—More care is demanded in selecting the position of the block in the representation of block mountains than in most of the preceding forms. This is true because, first of all, the block must present a good cross-section to show the characteristic structure; second, the steeper front of the block mountain must be well presented in order that the triangular facets and other typical features may be clearly portrayed; and third, the back slope must also, to some extent, be in view. Note now the three blocks in Fig. 104, which is drawn in two-point perspective. Of the three, block *C* is the most suitable. It presents a satisfactory cross-section and at the same time gives a view of the steep front slope and gentle back slope of the range. Block *B* is too high up, that is, it is too near the horizon line to show the back slope of the range. Block *A* is also too high, although the back slope is partly visible. It is also a little too far to the left to give a good front view of the range. Thus, it is evident that the block must be

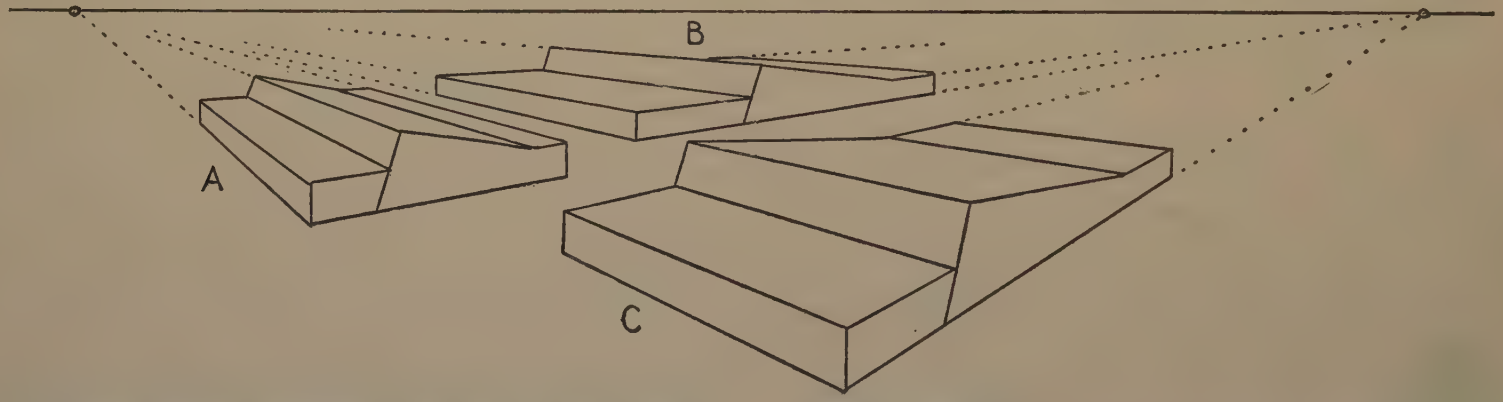


FIG. 104.—Block mountains, represented in block form, in three positions, two-point perspective. Block *C*, a bit to the right and well below the horizon, shows both the front and back slopes of the block mountain and also shows a good cross-section of the range.

placed very nearly as block *C* is placed in order to fill all the requirements satisfactorily. That is, it ought to be to the right of the median point between the two vanishing points, and far enough down to show the back slope of the range. Of course, the whole block may be reversed and placed to the left of the middle with the range facing to the right.

In Fig. 105 several blocks are shown in one-point perspective. The same principles hold here as in Fig. 104. Block *C* is the most suitable. Situated to the right and well down below the horizon, it gives a good view of the range and a full, undistorted structural cross-section. Block *D*, to the left of the vanishing point, does not show the steep face of the block mountain. Block *C* in Fig. 105 is deemed more satisfactory than block *C* in Fig. 104 because the one-point system is easier to use, and because it presents a better cross-section. This position will therefore be used in the following drawings.

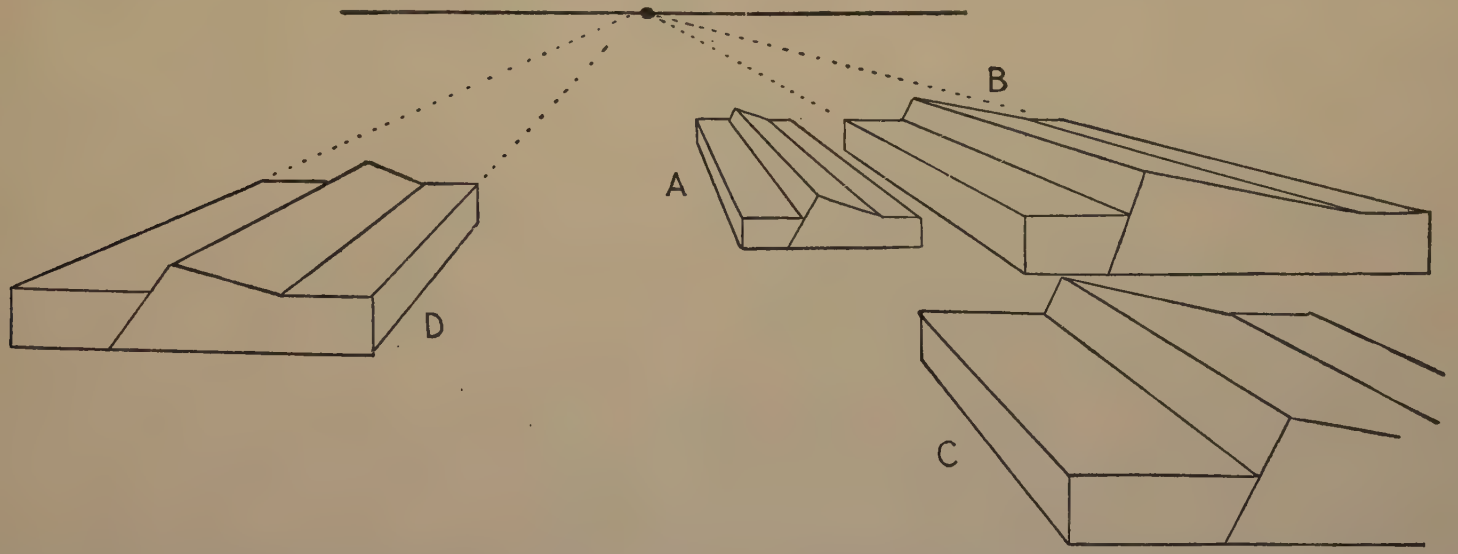


FIG. 105.—Block mountains, represented in block form, in several positions, one-point perspective. Block *C*, to the right and well below the horizon, shows both the front and back slopes of the block mountain and also an undistorted cross-section. This block is even better than block *C*, in Fig. 104, because the block in one-point perspective is easier to draw.

74. The block mountain; youthful stage of dissection.—The initial features of dissection may be represented in the form of a number of notches interrupting the front of the range. Figures 106 and 107 show how these notches should be drawn. Note that in the back part of Fig. 106, at *A*, two lines *ab* and *bc* have been drawn to represent what is to be the

medial position of the notch. Then at *B* the notch is represented symmetrically with respect to this medial line. Next, between *C* and *D* we consider breaking up the space between two notches, as a result of further dissection. The spur end between two notches, like that between *B* and *C*, is imagined as being interrupted by a smaller notch, which is drawn with the aid of medial lines in the same way as the larger notches on either side. Between *B* and *C* the dotted lines suggest the procedure, but between *C* and *D* the smaller notch is drawn in. It will be noted now that between *C* and *D* the triangular facets at the ends of the spurs do not rise to the crest of the range. Thus the crest is no longer at the front of the range, but is being gradually pushed back. Until this condition prevails throughout the range it is said to be young. Between *E* and *F* in Fig. 106 a little greater freedom has been given to the drawing by the avoidance of straight lines on the ridge crests.

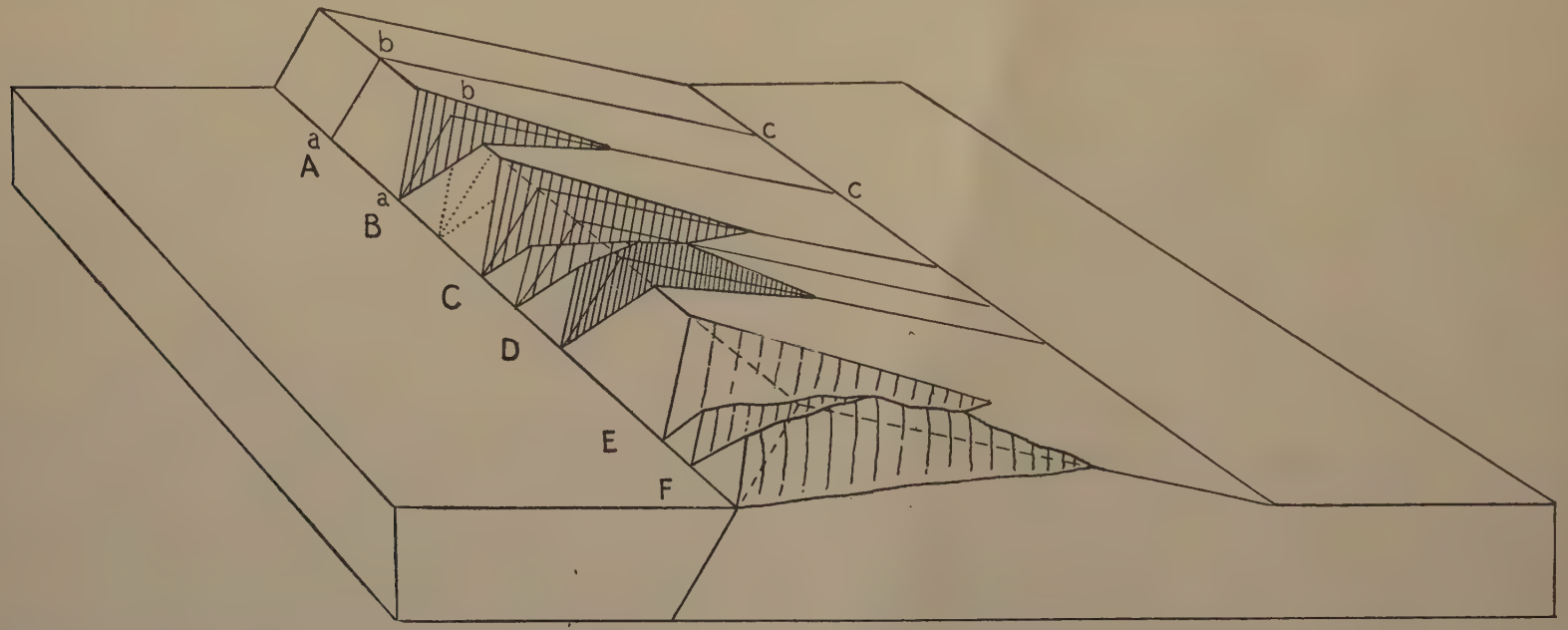


FIG. 106.—Young block mountain, showing first stages of dissection. The drawing of stream notches is facilitated by the use of construction lines *ab* and *bc*, shown in the back part of the drawing. These represent the trace of a vertical plane, with respect to which the notch is symmetrically placed.

Figure 107 illustrates in *B* the correct representation of a

notch, and in *A* the incorrect representation. In *B* the notch is symmetrically placed with respect to a medial plane which stands at right angles to the front of the range. It is true, of course, that streams cutting the front of a block range may have any position, even that of stream *A* in Fig. 107; but in a diagram one expects to see the more usual situation represented in a rather arbitrary manner. Therefore, it seems more desirable in simple drawings to follow the method here advocated.

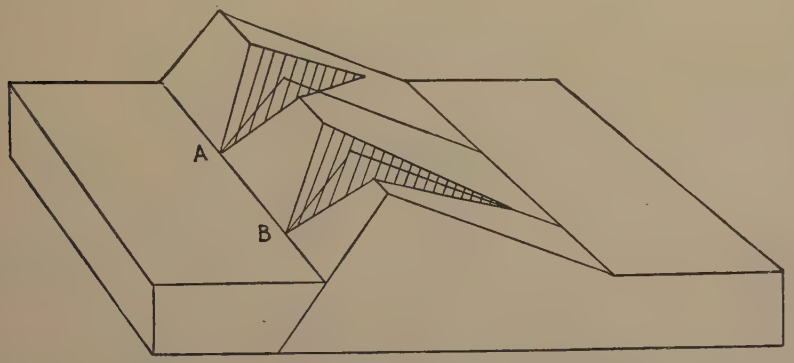


FIG. 107.—Block mountain showing notch *B*, symmetrically placed with respect to medial plane; and notch *A* not symmetrically placed. Notch *B* has a more natural appearance.

75. The block mountain. Mature stage of dissection.—The maturely dissected block mountain may be represented somewhat as shown in Fig. 108. It is desirable, in presenting this subject before students, that the teacher be liberal and show a considerable extent of the block range so that the student may visualize more readily the aspect of such a feature in its entirety. The drawing should show the triangular facets, but some of the smaller spurs may taper off to a point. The drawing will also show the crest of the range

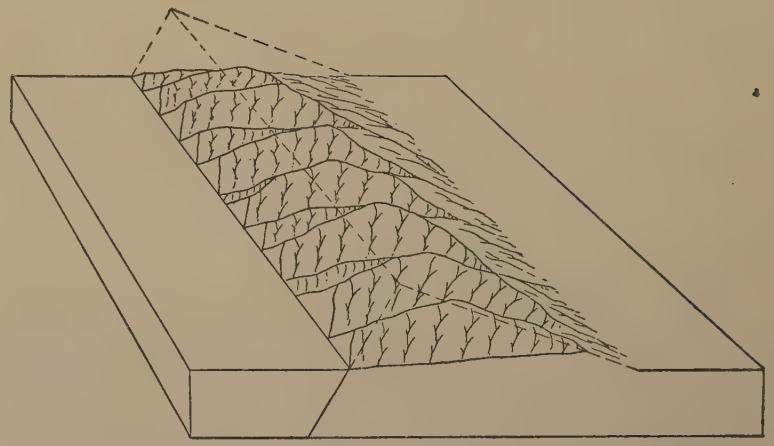


FIG. 108.—Mature block mountain, showing some of the diagnostic features, such as straight base line, continuous and uniform height of range, abrupt opening of valleys upon the plain, and the triangular facets at the ends of the spurs.

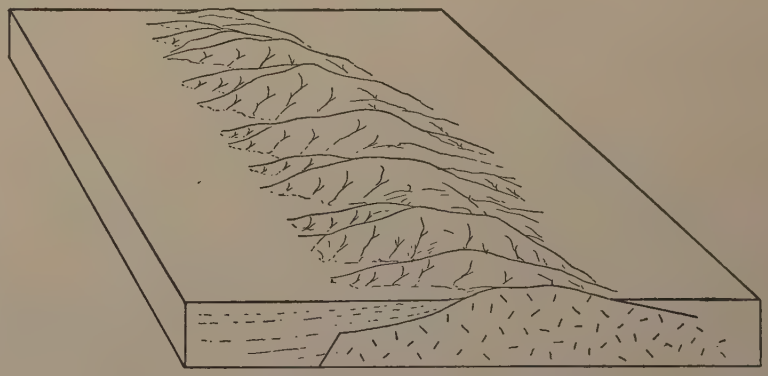


FIG. 109.—Old block mountain. Erosion has worn back the crest so that the front and back slopes of the range are equal. The foot of the range has been buried under the accumulation of alluvium.

well removed from its front. In fact, there is an approach to equality in the slopes on the back and front of the range. Fig. 108, to a certain extent, is a picture of the block mountains represented on most of the contour maps of the Great Basin. It may be used to impress upon the student the characteristics of the maturely dissected block mountain, such as the straight base line, the continuity and uniform height of the range, the abrupt opening of the valleys on to the plain, as well as the triangular facets at the ends of the spurs.

76. The block mountain in old age.—A very simple device, as in Fig. 109, may be resorted to in the representation of the last stages of a block mountain. The essential idea is to show that the triangular facets have disappeared and that there is approximate equality in the front and back slopes of the range. The cross-section suggests that the range has a reduced height above the plain, not only because it has been worn down, but also because it has been partly buried in its own waste or in the waste of some larger adjacent range.

77. Base of the range truncates the structure.—This important relationship is brought out in Fig. 110. It is important because it indicates that the range does not owe its straight form and continuous extent to a prevailing hard formation. No single formation extends for any great distance along the front of the range. Nevertheless, the range maintains its distinctive character throughout because it owes its form to uplift along a fault line.

The drawing of the geological structure upon a range involves some study, but the difficulties are not great. Since problems of this general character are likely to arise in all phases of this work, a few specific suggestions will here be offered. Examine Fig. 111. Block 1 represents a block mountain into which a single notch has been cut, similar to those in Figs. 106, 107, and 110. The problem before us is the representation of the geological structure upon the different parts of this block mountain. For example, suppose a dipping sedimentary series is to be represented. In block 2 we have drawn the line AB to represent the outcrop of one bed upon the front of the block mountain. Any suitable position for AB may be selected, depending upon the demands of the problem. Next, in block 3, we consider the outcrop

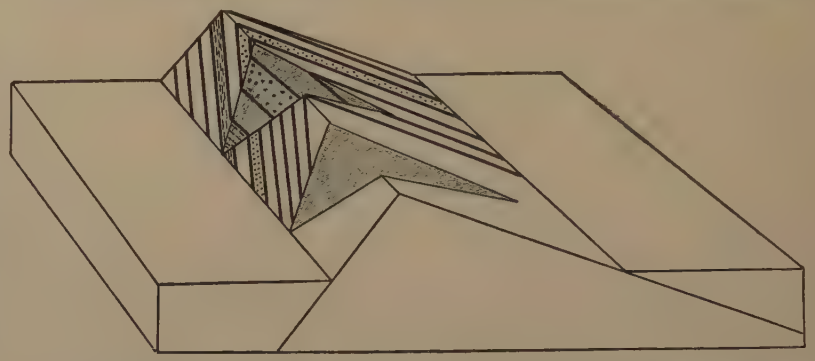


Fig. 110.—Block mountain composed of tilted sedimentary formations. The formations were tilted prior to the faulting which raised the block. Consequently the face of the block mountain truncates the structure.

of this same formation upon the back slope of the block mountain. Here again, any position may be chosen. Thus AC has been drawn. The drawing of the two lines AB and AC fixes the attitude of the formation. Our task is now before us. It consists in determining, first, the outcrop of the formation on the wall of the gorge, and second, the position of the rock layer on the cross-section of the block toward the observer. Note Fig. 111, block 4. The problem is to determine the position of the line ST. Extend CA and EP until they intersect at D. This gives the point D where the

formation would outcrop at the rim of the gorge if the gorge were longer downstream. Since the formation outcrops at the point S on the wall of the gorge, the line DS, extended to T, represents its continuous outcrop on the wall of the gorge. This whole procedure may be reversed if the outcrop on the wall of the gorge is already given and the problem is to determine the outcrop on the back slope.

Next, in block 5, Fig. 111, we determine the line BJ on the cross-section. Extend AC and GK until they intersect at F. Extend AB and MN until they intersect at H. Draw FH, which intersects the horizontal line NG at J. Draw BJ. The procedure involves simply the determination of the intersection of the plane of the formation with the horizontal plane $MNKG$ so as to locate the point J. Here again the line BJ may rather be accepted as a known quantity, leaving one of the other lines to be determined. Thus any two adjacent lines of the four lines, AB, AC, ST, and BJ, may be given, or drawn at random, the problem then being the determination of the other two.

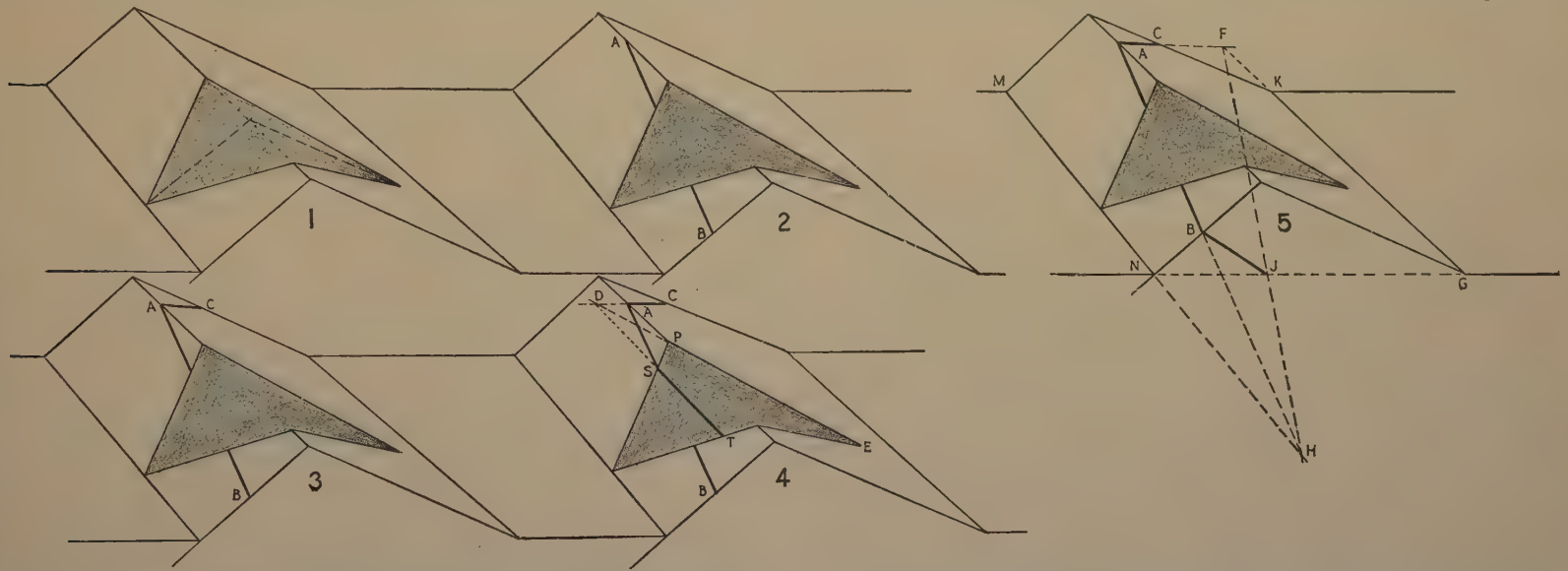


FIG. 111.—Series of blocks to illustrate method of drawing geological structure on the front slope of the block mountain, the back slope of the block mountain, the wall of the notch, and the cross-section, if the outcrops on two adjacent planes are given. Block 4 shows how to find the outcrop on the wall of the gorge, given the outcrops on the front and back slopes of the block mountain. Block 5 shows how to determine the outcrop on the cross-section, given the outcrops on the front and back slopes of the block mountain. See Section 77 of the text for details.

78. Minor details of block mountains.—Owing to recent faulting, many of the alluvial fans or deltas at the base of various ranges, like the Wasatch, have been slightly dis-

placed so that terraces result. Terminal moraines left at the mouths of the canyons by local valley glaciers also show the

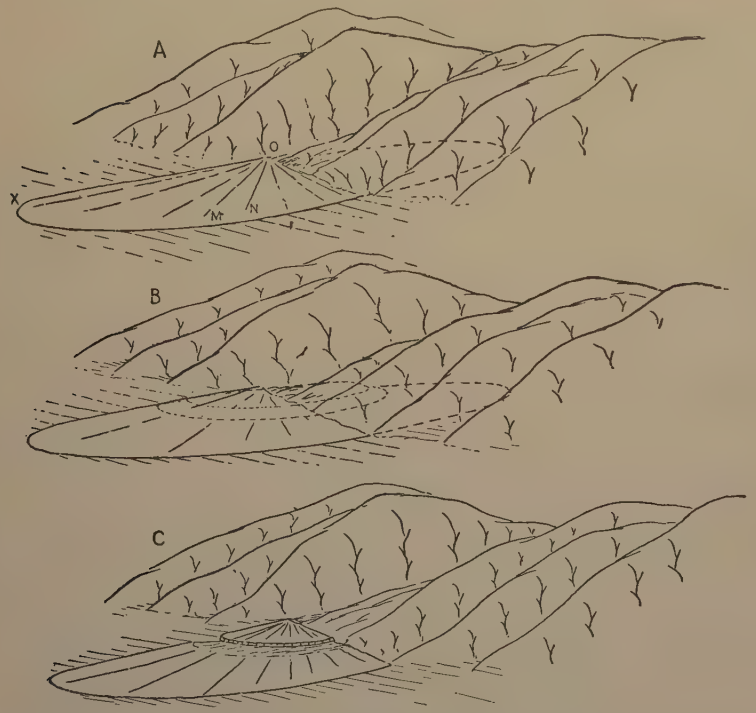


FIG. 112.—Rough sketches showing alluvial cones at the base of maturely dissected block mountain. Sketch *A* suggests the use of the ellipse in drawing the cone. Sketch *C* represents a horizontal terrace produced in the cone by wave action. The drawing of this terrace is aided by the use of smaller ellipses as shown in sketch *B*.

effect of recent movement. When these features occur in a region where the terraces of Lake Bonneville are also to be found, it is necessary to distinguish between the different kinds of terraces. This distinction may be represented as in Figs. 112 and 113. Fig. 112, *A*, represents the front of a block range. From the mouth of one of the canyons extends an alluvial fan. This is drawn by the use of half an ellipse for the base. The entire ellipse has here been indi-

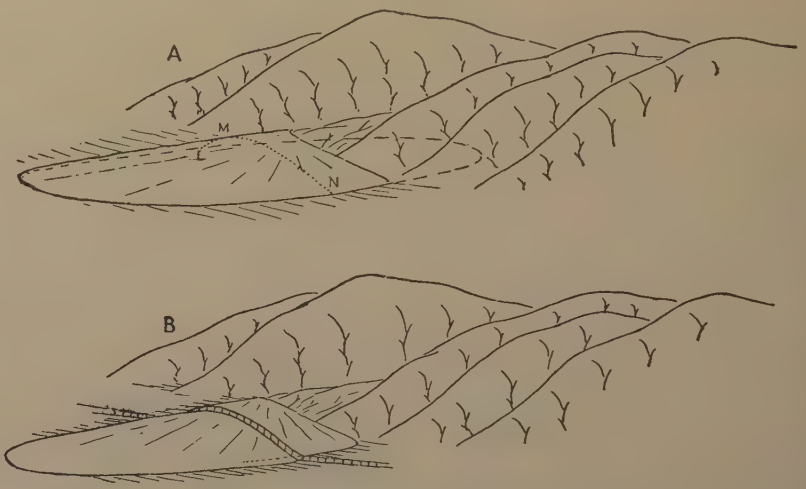


FIG. 113.—Rough sketches showing alluvial cones at the base of a maturely dissected block mountain. In sketch *B* the cone has been offset by a vertical fault which runs parallel with the front of the range. The dotted line *LMN* in sketch *A* shows the intersection of the fault plane with the cone.

cated to suggest the construction. Then, from a point *O* above the center of the ellipse, draw *OX* tangent to the ellipse to represent the profile of the cone. Complete by drawing the radiating lines *OM*, *ON*, etc., down the slope of the cone. Next, in Fig. 112, *B*, we proceed to terrace this cone by cutting it with a horizontal plane. This is the type of terrace produced by wave cutting and is represented by

the Bonneville shorelines cut on the alluvial fans of the Great Basin region. To draw this terrace, indicate other ellipses midway up the cone, as shown in Fig. 112, *B*. Like the basal ellipse, these smaller ellipses should also be tangent to the profile of the cone, *OX*. Complete the drawing as shown in Fig. 112, *C*.

To represent the type of terrace produced by an uplift of the range, proceed as in Fig. 113. This type of terrace is developed along a vertical or almost vertical plane. Fig. 113, *A*, represents the front of the range. An alluvial fan spreads out on the plain. Draw the line *LMN*, as shown, to represent the intersection of a vertical plane with the surface of the fan. Next, as in Fig. 113, *B*, drop down the front end of the cone and complete the drawing. A terrace of this type, due to faulting, is produced by a vertical plane, and climbs up over the cone, whereas the terrace shown in Fig. 112, *C*, is produced by a horizontal plane and goes around the cone.

79. Specific example: young block mountain, San Pedro sheet, New Mexico.—The Sandia Mountain Range may be selected as one of the best examples of a young block mountain to be found on topographic maps. It has been dissected so little as to be almost diagrammatic in its simplicity. Fig. 114 shows its main characteristics, as seen from the back of the range. The block may be turned so that the observer faces the steep front of the range, but if this is done, the gentle back slope should at the same time be suggested. The cross-section indicates clearly the block character of the range. The internal structure of a block mountain may be simple or complex. In this case a granite core is capped by a layer of limestone, practically undisturbed except for the tilting due to faulting.

80. Specific example: mature block mountain. Disaster sheet, Nevada.—Like most of the sheets of Nevada and western Utah, this map shows the block ranges and basins of the so-called Basin and Range Province. But few of the typical details of dissected block mountains are to be identified upon this map, largely because the scale is too small and the contour interval too great. The ranges in

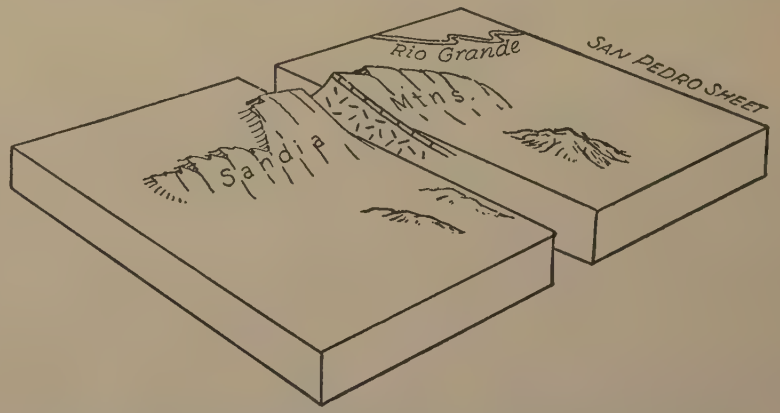


Fig. 114.—Block diagram of San Pedro sheet, New Mexico, showing in a simple manner the essential form of a young block mountain.

general have a north-south trend and a straight or only gently curving base line. One side of each range usually appears to be somewhat steeper than the other side, thus occasionally suggesting the position of the fault. Some of the basins, for this reason, appear to be down-dropped blocks or grabens rather than basins bounded by one fault and lying between tilted blocks. Kings Valley is apparently of this type. Northeast of Kings Valley, the Disaster Peak Range is a rather youthful example of a block mountain tilted gently eastward. Among other points of minor interest are the

hot springs, usually located upon the fault zones, and the intermittent streams emerging from the mountains to spread out their burden of alluvium in the form of broad, sloping fans upon the basin floors where the desert winds blow up the fine dust into dunes.

81. Other examples of block mountains.—Practically all of the maps covering the Great Basin of Nevada and western Utah depict block mountain features. Among those which

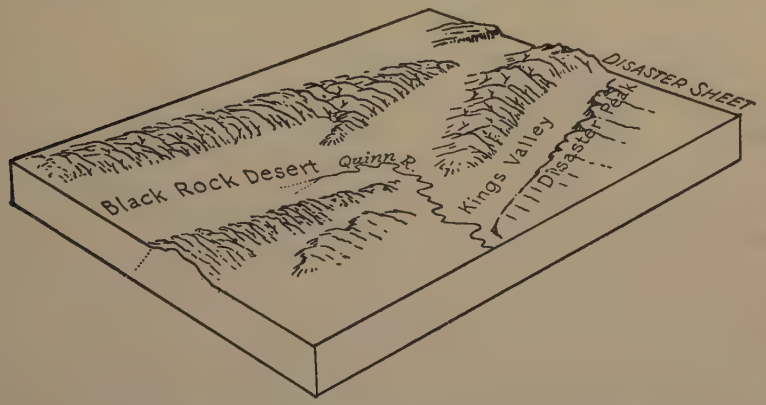


FIG. 115.—Block diagram of Disaster sheet, Nevada, showing young as well as mature block mountain, grabens, and block basins.

are especially suitable for study, and which at the same time lend themselves to representation in block-diagram form, is the Carson Sink quadrangle of Nevada. On the map the straight base line of Stillwater Range unquestionably indicates a fault line. Humboldt Range similarly has a straight trend. Among the minor features of interest represented on this map is the old beach of Lake Lahontan at the foot of Stillwater Range. The road to Winnemucca passes between the beach ridge and the range. At the south end of Humboldt Lake, near Ocala, is the remnant of a sand spit connecting Humboldt and Trinity Ranges. A road follows part way along its crest.

The Fish Springs sheet, Utah, is equally prolific. On this map, House Range shows distinctly its block character by its steep western face and gentle eastern slope. In Confusion Range the effect of transverse faulting is also strongly brought out in its southern part. Still other useful maps are Furnace Creek quadrangle, California and Nevada, which shows part of the down-dropped graben of Death Valley; the Tooele Valley sheet in Utah, showing block mountains standing up as islands in Great Salt Lake; and the Sevier Desert sheet in Utah, which shows the interesting Sevier Canyon cutting across the Canyon Range, apparently as an antecedent river. All of these maps, and many others in addition, can well be utilized as subjects for perspective or block drawings to illustrate the varied features of block mountains.

82. Fault cliffs, fault-line cliffs, and other features due to faulting and jointing.—Many maps from the Colorado Plateau region of the United States illustrate features due either directly or indirectly to faulting. The great escarpments which limit the western side of the plateau blocks in the Grand Canyon district are generally thought to be fault-line cliffs, though in some cases faulting is actually responsible for the differences in elevation. The Kaibab sheet, Arizona, shows two large fault-line cliffs on the western side of the Kaibab Plateau; the eastern side of the plateau descends by two monoclines toward House Rock Valley. Kanab Plateau descends westward over the Toroweap fault-line cliff to Toroweap Valley and Uinkaret Plateau, shown on the Mt. Trumbull sheet, Arizona. West of Uinkaret

Plateau is the great Hurricane Ledge, a fault escarpment which overlooks Shiwits Plateau. Finally, the Grand Wash Cliffs, a fault escarpment a thousand feet or more in height, overlooks the Great Basin.

The maps of the Swedish lake district show clearly the escarpments developed along fault lines by erosion after peneplanation. Figure 74, on page 169, in Davis' *Erklärende Beschreibung der Landformen*, presents clearly the type of physiographic development which has occurred, without attempting to represent any features in particular. On the Swedish maps, scale 1 : 100,000, the peculiar forms resulting from such development may be noted, especially on the Vimmerby and Linköping sheets, Nos. 36 and 45. However, the larger Swedish lakes, Wenner and Wetter, illustrate even more boldly the effect of faulting. Lake Wetter is a good example of a long graben, Mount Omberg on its eastern shore standing up as a horst above the surrounding country.

The great Rhine Graben is impressively shown on a group of the German topographic maps, scale 1 : 100,000, especially sheets Nos. 526, 527; 543, 544; 557, 558; and 572, 573.

The effect of faulting, followed by peneplanation and later erosion, upon tilted alternating weak and resistant beds, is illustrated by the features in the Connecticut Lowland. Fig. 116 shows the successive stages which result when an eastward-dipping resistant formation is cut by a vertical fault, the area to the north uplifted, the whole area then peneplaned and dissected. Fig. 117 illustrates a slight modification resulting from a diagonal fault. Several other combinations are possible, depending upon direction of dip of formations, number of resistant formations, direction of fault strike, and amount and character of displacement.

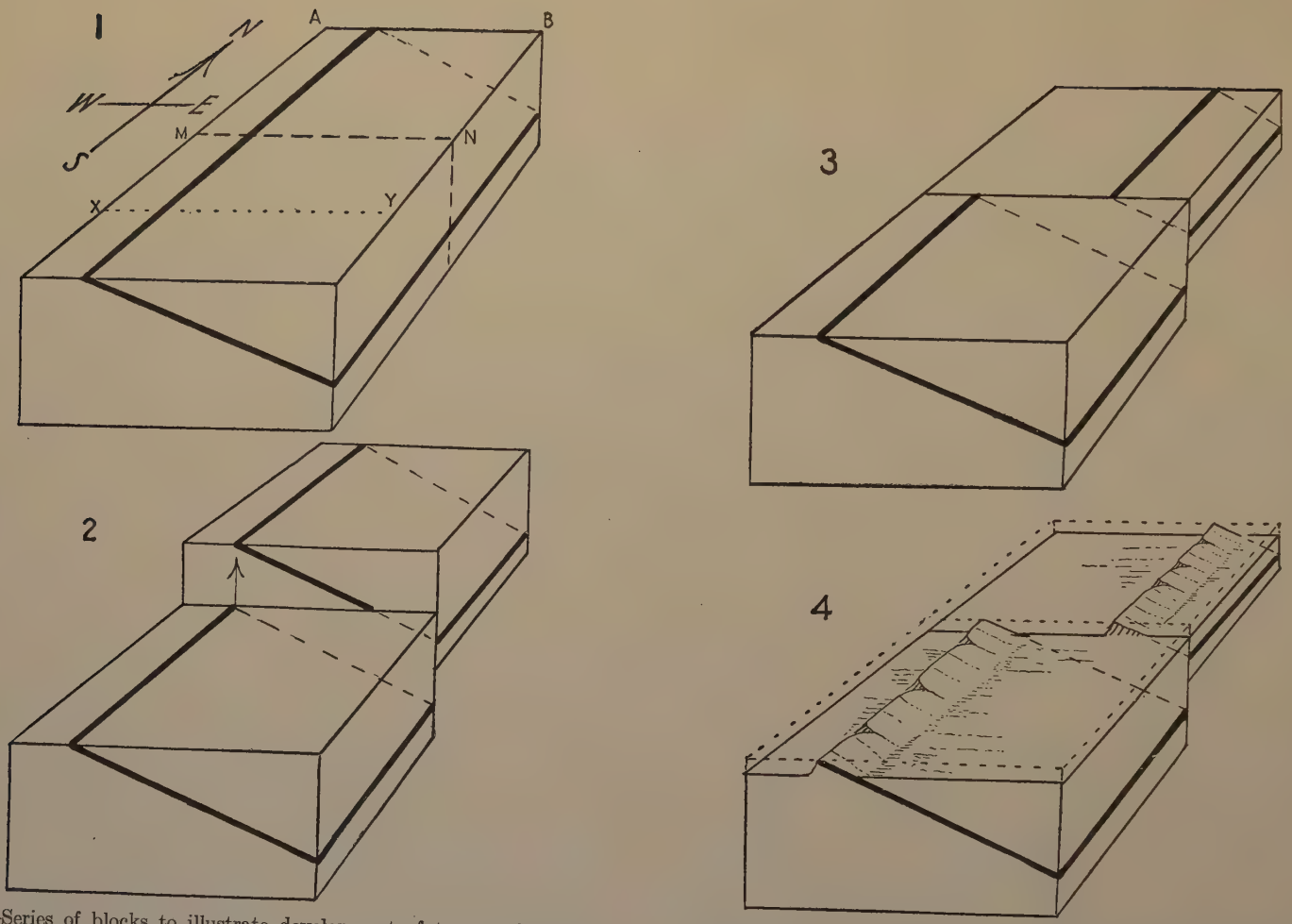


FIG. 116.—Series of blocks to illustrate development of topographic forms upon eastward dipping weak and resistant formations, cut by east-west fault, the area to the north being uplifted, the whole then peneplaned and dissected.

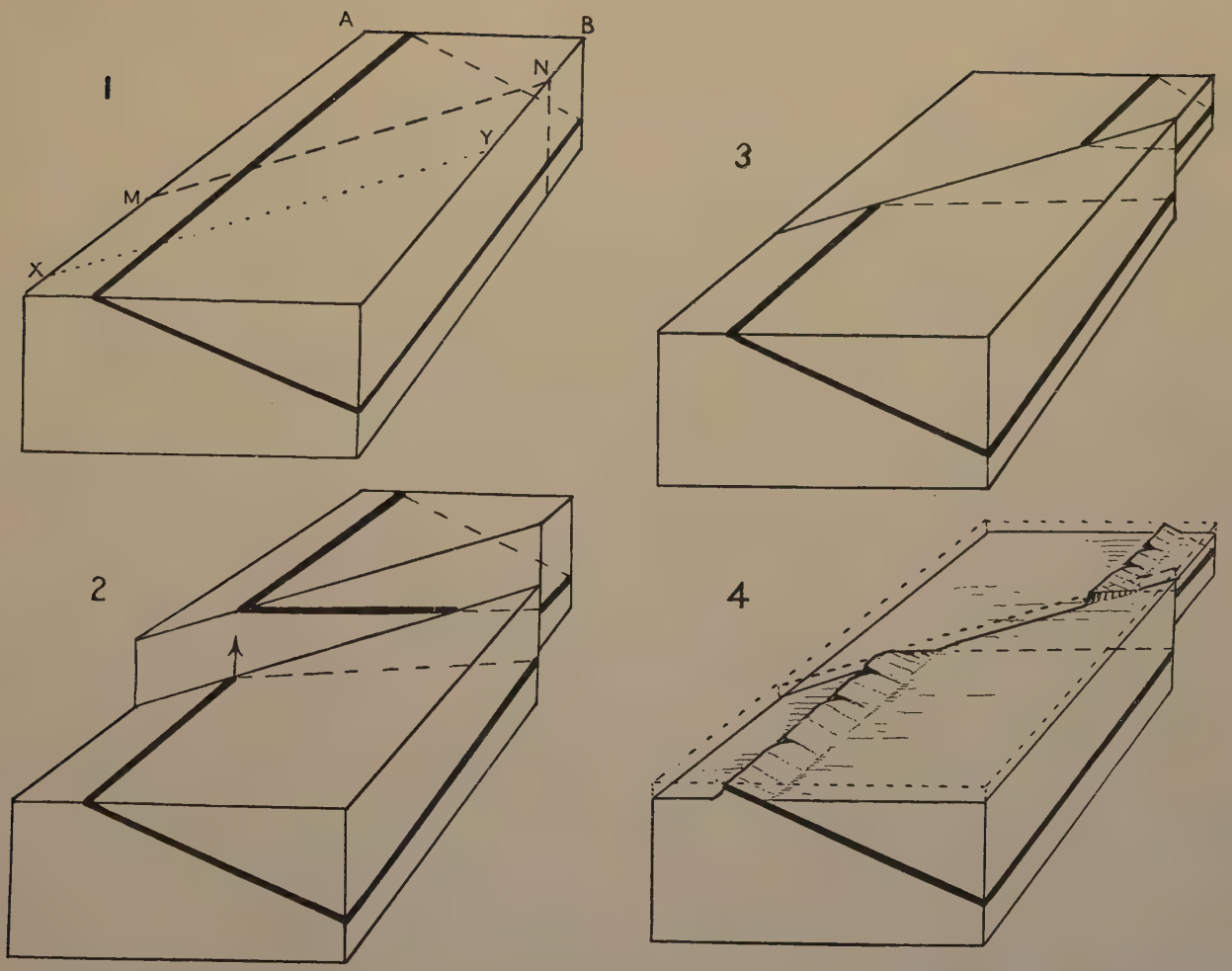


FIG. 117.—Series of blocks to illustrate development of topographic forms upon eastward dipping weak and resistant formations cut by northeast-southwest fault, the area to the north being uplifted, the whole then peneplaned and dissected.

EXERCISES

Based upon the Illustrations in Chapter VII

Exercise 1. Draw a block similar to *C* in Fig. 104, in two-point perspective, but reversed so that the steep slope faces toward the right instead of toward the left.

Exercise 2. In Fig. 105, draw a block similar to block *C*, in one-point perspective, but reversed so that the steep slope faces toward the right instead of toward the left.

Exercise 3. Complete the dissection of Fig. 106 by introducing additional notches in the manner indicated.

Exercise 4. Complete Fig. 110 by representing the structure in the nearer notch and on the cross-section.

Exercise 5. Complete Fig. 111, block 3, by determining the outcrop of formation *CAB* in wall of gorge and on the cross-section.

Exercise 6. On Fig. 111, block 3, slightly alter the position of *AC* and *AB*. Then determine the outcrop on wall of gorge and the cross-section.

Exercise 7. On a block similar to block 3 of Fig. 111, indicate assumed outcrops of a tilted formation on wall of gorge and on front of range. Then determine outcrop of same formation on back slope, and its position in the cross-section.

Exercise 8. Prepare a sketch similar to Fig. 113, showing a horseshoe-shaped moraine built out on the plains by a local glacier descending one of the canyons of a block mountain. Then indicate the appearance of the moraine after it has been displaced by faulting which has caused renewed uplift of the range.

Exercise 9. Redraw Fig. 116, placing the four blocks touching each other, side by side, so as to show the successive stages from left to right in order to gain compactness.

Exercise 10. Revise the drawing just completed under Exercise 9 by introducing another vertical fault at *XY*, Fig. 116, block 1. The block *MNXY* is uplifted about one-half as high as block *ABMN*, the other blocks maintaining their positions as drawn. Represent all stages.

Exercise 11. Redraw Fig. 117, placing the four blocks touching each other, side by side, so as to show the several stages from left to right.

Exercise 12. Revise the drawing just made under Exercise 11 by introducing another vertical fault at *XY*, Fig. 117, block 1. The block *MNXY* is uplifted about one-half as high as block *ABMN*, the other blocks maintaining their positions as shown. Represent all stages.

Exercise 13. Prepare a series of four drawings, similar to Fig. 117, showing the successive forms resulting from faulting, peneplanation, and later dissection of a region in which the fault crosses the strike of the formations obliquely in the other direction; i.e., if the formation dips eastward, the strike of the fault should be northwest-southeast. The same type of features would result if the formation dips west and the strike of the fault is northeast-southwest, the blocks to the north in each case being successively elevated with respect to those to the south.

Exercise 14. Prepare a series of sketches, hachure maps, or other simple device, to show the wide range of possible forms, similar to those represented in Figs. 116 and 117, resulting from various combinations of dip, direction of fault, strike, and other factors.

(Exercises Based upon Topographic Maps)

Exercise 15. Prepare a block diagram of the Kaibab and Mt. Trumbull sheets, showing topography and structure.

Exercise 16. Prepare a block diagram of the Swedish lake area, especially that covered by the map of Sweden, 1 : 100,000, sheets Nos. 33, 34, 35; 42, 43, 44; 52, 53, 54; 62, 63, 64. Use map of "Landforms in the surroundings of the Great Swedish Lakes" by Sten de Geer, scale 1 : 500,000, showing position of faults and giving cross-sections, published by Swedish Geological Survey.

Exercise 17. Prepare block diagram of part of Rhine Graben, using the maps mentioned in Section 82, and any other available data for cross-sections or geological structure.

Exercise 18. Prepare block diagram of the Meriden sheet, Connecticut, representing several stages in the development of the area. In the Hanging Hills two or three resistant beds, dipping to the east, are cut by northeast-southwest faults, the blocks to the south having been successively elevated, peneplaned and dissected.

CHAPTER VIII

COMPLEX MOUNTAINS

83. The undissected mountain mass.—It is convenient in the drawing of complex mountain regions to have in mind the shape of the massif before dissection. It is not necessary always to outline this form, though occasionally a sketch like Fig. 118 may be found useful.

84. Dissection of the mountain mass; rounded forms.—The breaking up of the undissected mass may be thought of from two standpoints: first, the stream valleys may be foremost in mind; or second, the divides between the streams may be thought of as the essential features. Let us note the procedure in each case. Figure 119 shows several stages in the representation of a series of streams flowing over a rounded dome-like mass. The procedure is similar to that which has already been explained for the drawing of streams on a plain (Section 26). A wavy or zigzag line represents the stream. From its curves tangents are drawn upward to represent the valley spurs, and further embellishment gives life to the drawing. (Fig. 119, *C*).

FIG. 118.—A rounded upland of crystalline rock before dissection.

The other method is illustrated in Fig. 120. As in the previous case, zigzag lines are drawn, but now they are intended to represent not the bed of the stream but the crests of the divides between the streams. The spur lines, instead of being carried upward, are carried downward, as

FIG. 119.—The upland shown in Fig. 118 with stream courses added. In *A* the wavy line represents the channel of the stream; in *B* the spur lines have been drawn tangent to the sharp elbows of the stream; in *C* a little shading on the spur slopes emphasizes the relief.

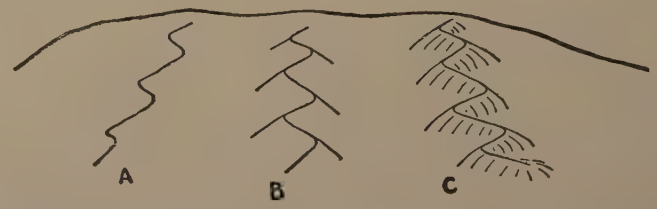


FIG. 120.—In this case the relief is developed on the crystalline upland by drawing the spurs rather than the valleys, following the three stages shown in *A*, *B*, and *C*.

shown in *B* of Fig. 120. Additional embellishment again adds realism to the drawing.

In Fig. 121, the drawing is carried a little further but with no change in method. Fig. 121, *A*, represents the device used in Fig. 119, but tributaries have been added to the streams and the spur lines from one stream are carried over the divide between streams so as to connect with the spurs of the adjacent stream, thus rounding out the slope and giving a certain completeness to the drawing. Figure 121, *B*, utilizes the device shown in Fig. 120. The ridge lines have been carried down from the mountain crest and the spurs from one ridge are allowed to interlock with those of the

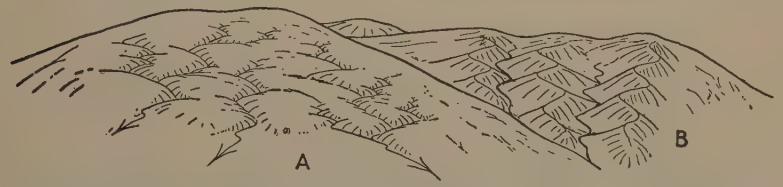


FIG. 121.—Further dissection of the upland represented in the previous figures, by the addition of tributaries.

adjacent ridge. In the valleys thus formed, streams have been introduced.

85. Dissection of the mountain mass: angular forms.—If the mountain mass is to be characterized by sharp peaks it is well to draw the serrate crest line first, allowing some peaks to rise up in the distance between those in the foreground, as in Fig. 122. Then proceed with the ridge device used in Fig. 120. Figure 123 illustrates the representation of complex mountains as isolated masses on a block drawing. Both sharp-crested and rounded forms are indicated.

86. Specific example: rejuvenated old complex mountains: Ramapo quadrangle, New York-New Jersey.—The aspect of an old complex mountain mass is much like that of a plain. If such a mountain mass is elevated and subjected to renewed dissection, it resembles a plateau in many

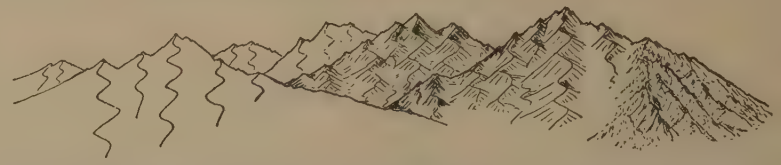


FIG. 122.—Treatment of a serrate mountain mass by the drawing of spurs from the peaks.

respects. The drainage will usually be dendritic, but probable with some tendency to flow in one direction more than in any other. This is because most regions of complex rocks have been subjected to pressure, with the resulting develop-

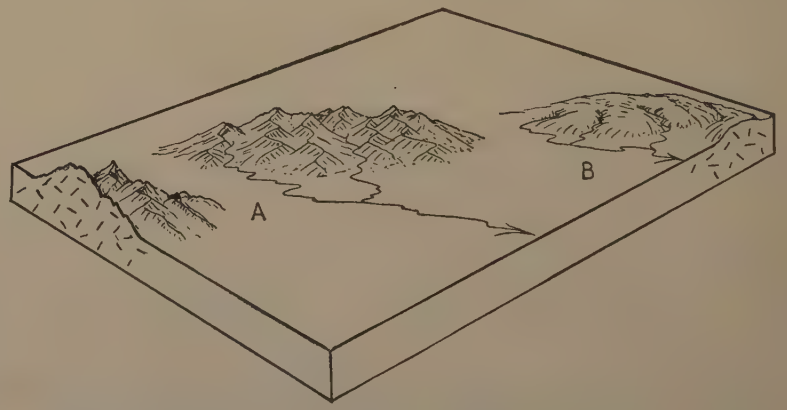


FIG. 123.—Isolated complex mountain areas represented on a block.

ment of schistosity or sometimes of joint systems which control the drainage. The Ramapo quadrangle is presented in Fig. 124. Half of this area, known as the Ramapo Mountains, represents an uplifted peneplane developed on

complex crystalline rocks. A slight northeast-southwest trend is recognizable in the drainage but to a large degree it is dendritic in pattern. In the drawing of this upland, it is suggested that the same device be followed as in the representation of plateaus with rounded forms, as shown in Fig. 58, *E*. The margins of an upland like this will in no case show benches or steps such as are likely to be present along plateau margins, as on the Kaaterskill, N. Y., sheet in

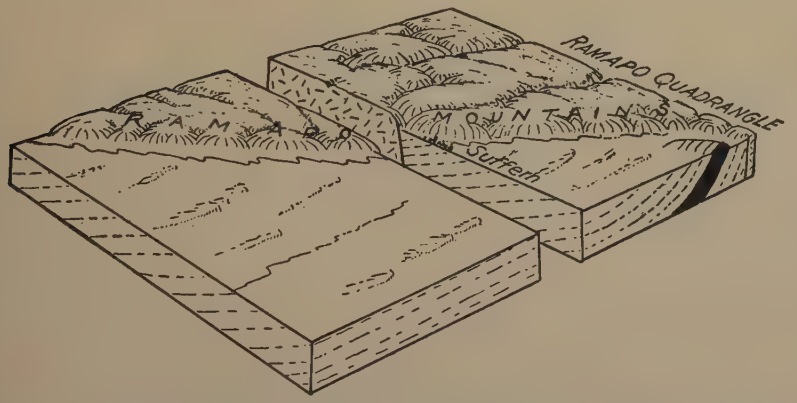


FIG. 124.—Block diagram of Ramapo quadrangle, New Jersey. Complex mountains make up half the area.

the Catskills, or the Hollidaysburg, Pa., sheet along the Allegheny Front.

The remaining southeast portion of the Ramapo sheet portrays a part of the Triassic Lowland with its westerly dipping sandstones. The small topographic features all have a north-south trend in common with the strike of the underlying rocks. The tip end of the Palisades also appears on this map, in its northeast corner.

Another map showing a dissected upland is the Hawley, Mass., sheet which may be portrayed in much the same way as the Ramapo Mountains (See Fig. 148).

87. Other examples of complex mountains.—The Raquette Lake sheet, New York, may be taken as a typical complex mountain region, maturely dissected. No upland is evident and the region is essentially a maze of rounded peaks. There is, however, a well-marked trend in the direction of the features. If drawn on a fairly large scale, a very attractive bird's-eye view of this region could be prepared along the lines already suggested. Other Adirondack Mountain maps illustrating mature complex mountains are the Mt. Marcy and Elizabethtown quadrangles. These two maps show a notable trellis, or right-angled, drainage pattern which breaks the mountain masses up into rectangular blocks like a checkerboard. This is due to the prevailing joint or fault systems. A study of the maps which have been suggested will acquaint the student with the general characteristics of complex mountain areas. In the course of this study he will do well to keep in mind the fact that jointing, faulting, and schistosity will exert a control upon the streams so as to induce a trend or pattern which departs from the dendritic type usually associated with regions of homogeneous rocks.

Some of the German topographic maps, scale 1 : 100,000, covering the Vosges Mountains and Black Forest, are excellent examples of complex mountain regions, as for instance Nos. 601, 603, and 617. No. 603 shows in addition the straight fault escarpment bounding the Black Forest mass.

The map of France, scale 1 : 200,000, sheet No. 80, Bastia, and No. 81, Ajaccio, depicting the larger part of Corsica, illustrate well the rugged aspect of mature complex mountains. The structure, however, is not entirely homo-

geneous, but has a prevailing northeast-southwest direction which is reflected in the trend of the physical features.

The British Ordnance Survey maps of the Scottish Highlands, on the scale of one inch to a mile, and many of the Norwegian and Swedish maps, scale 1 : 100,000, represent the rugged topography of complex mountains.

EXERCISES

Based upon the Illustrations in Chapter VIII

Exercise 1. On Fig. 118, represent stream courses similar to *A* on Fig. 119.

Exercise 2. Complete Fig. 119 so that streams *A* and *B* resemble stream *C*, and add tributaries.

Exercise 3. Complete Fig. 120 so that streams *A* and *B* resemble stream *C*. Extend the tributary spurs so that they interlock, as in *B* of Fig. 121, and represent the streams in the valleys thus formed.

Exercise 4. Complete Fig. 122.

(Exercises Based upon Topographic Maps)

Exercise 5. Prepare block diagram of the Raquette Lake sheet, New York.

Exercise 6. Select, from the British Ordnance maps and from the Norwegian and Swedish maps, typical sheets illustrating the irregular forms of maturely dissected complex mountains. Represent the essential topography in block-diagram form.

CHAPTER IX

VOLCANOES

88. Application of the cone to volcanic forms.—It has already been suggested that the cone may be utilized in the drawing of several types of land forms. Young volcanoes or cinder cones, as the very name implies, are conical forms, presenting almost no difficulty in their representation. The only difficulty arises in the introduction of modifications due to erosion or to volcanic flows from the sides of the cone. Figures 125, 126, 127, and 128 (from Davis' "Practical Exercises in Physical Geography") present in four stages a region subjected to vulcanism. The legends fully explain the development of the region. The student will do well to note the clever use of shading to differentiate the lava flows from the hills around them.

Figure 129 represents a volcano with a crater lake occupying a caldera or basin on its summit. The cross-section of the lava layers in the rim of the crater is nicely suggested. In Fig. 130 further vulcanism has produced a younger volcano or cone within the earlier caldera, thus simulating the situation at Vesuvius.

89. Specific examples of volcanic forms.—

a. Cinder Cone, California. This interesting topographic form, shown on the Lassen Peak quadrangle and described in Folio 15, is represented in Fig. 131, as seen from a neighboring and somewhat higher hill. A picture of this kind, made up altogether of simple land forms, should present no difficulty whatever to the teacher who wishes to sustain interest by a quickly drawn sketch on the blackboard.

b. Corvo and Flores in the Azores. Figures 132 and 133, from the Hydrographic Charts, give the aspect of these volcanic islands as seen in plan. The excellence of these maps, however, makes it easy to visualize the topographic forms, and the numerous elevations should make it possible to prepare bird's-eye views which closely resemble the features themselves.

The Crater Lake National Park sheet, Oregon, offers a splendid subject for a block diagram. If Professional Paper 3 is studied in connection with it, some cross-sections may be added, or at least the different surface flows may be differentiated on the drawing.

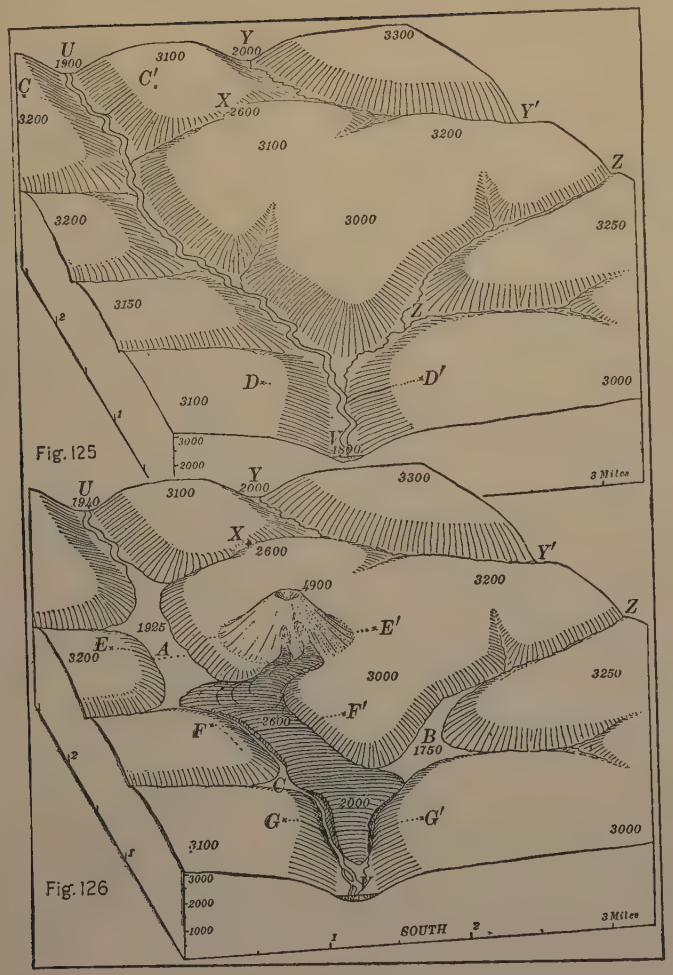


Fig. 125.—A region normally dissected by streams; later to be affected by vulcanism. (From W. M. Davis, by permission of Ginn & Co.)

Fig. 126.—The same region with a young volcanic cone from the side of which extends a lava flow down the valley. Streams have been blocked to form lakes at *A* and *B*. (From W. M. Davis, by permission of Ginn & Co.)

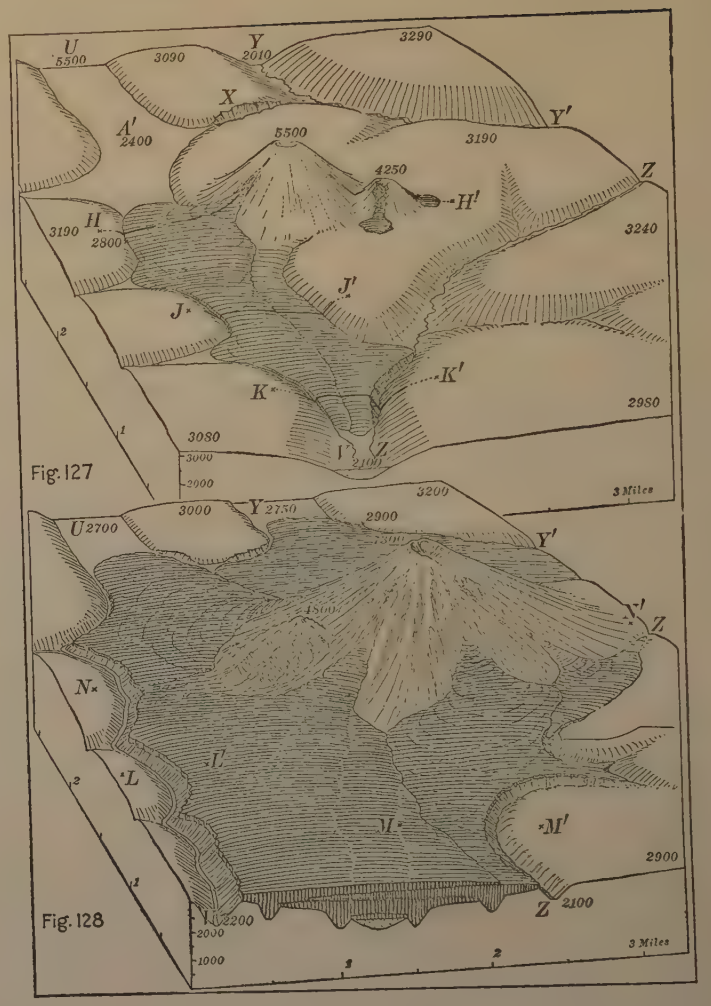


Fig. 127.—Further development of Fig. 125. A second cone has become active. The first cone has several eruptions to its credit. (From W. M. Davis, by permission of Ginn & Co.)

Fig. 128.—The second cone has become very large, and many lava flows coming from its flanks are shown in cross-section in the foreground. Deep lakes dammed in by lava flows occur at *U* and *Y*. The first cone is much dissected. (From W. M. Davis, by permission of Ginn & Co.)

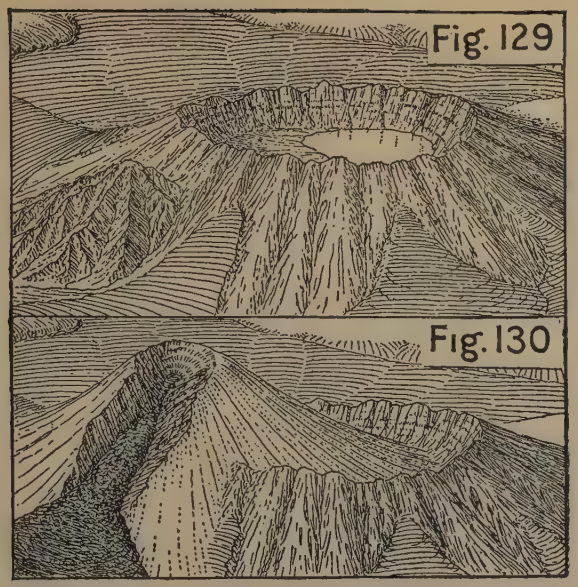


Fig. 129.—A volcanic cone surmounted by a caldera containing a "crater lake." On the left flank of the cone is an older cone, much eroded. (From W. M. Davis, by permission of Ginn & Co.)

Fig. 130.—Growth of a new cone partly within the caldera shown in Fig. 129. The new cone is but little eroded and is fairly symmetrical except for the lava flow on one side. (From W. M. Davis, by permission of Ginn & Co.)

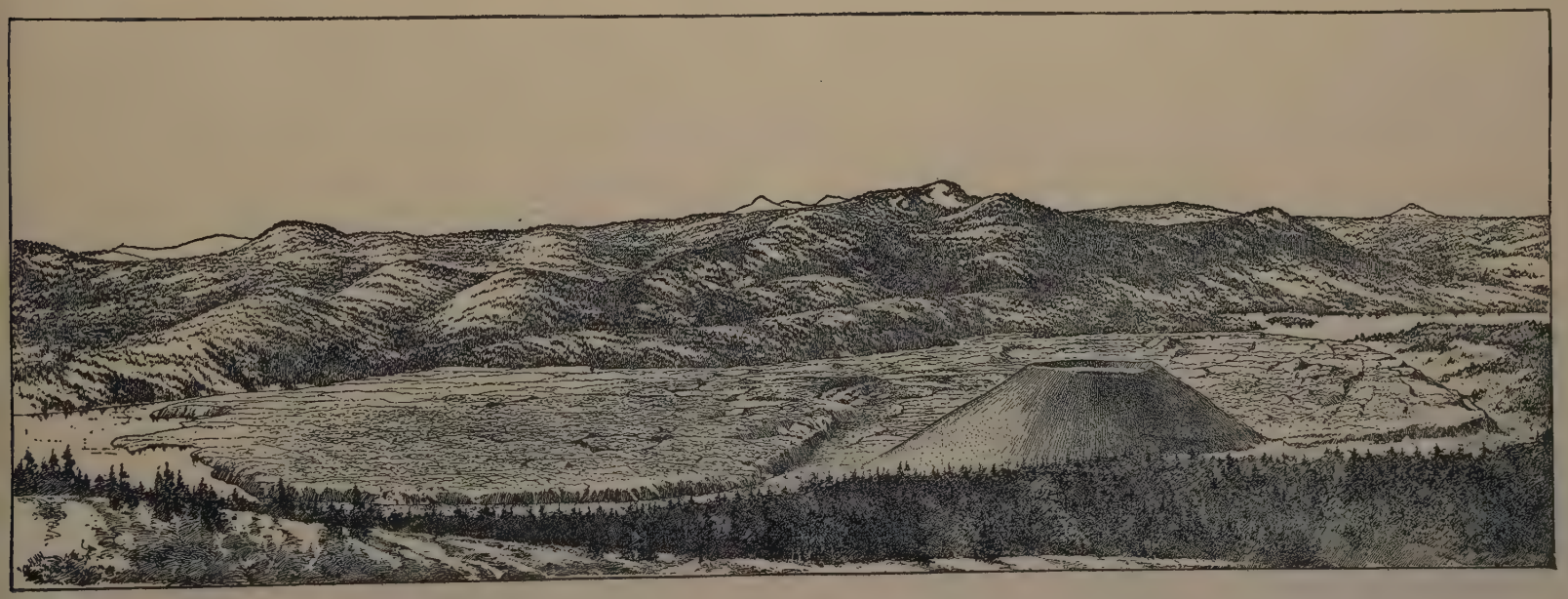


Fig. 131.—Cinder Cone, near Lassen Peak, California, viewed from a higher cone near by. Lava flows from the base of Cinder Cone, and from other cones not in the view, extend across the valley and have blocked it in several places to form lakes. (From U. S. Geol. Survey.)

FIG. 132.—Map of Corvo, Azores Islands, from U. S. Hydrographic chart. A volcano surmounted by caldera containing lakes.

EXERCISES

BASED UPON THE ILLUSTRATIONS IN CHAPTER IX

Exercise 1. On Fig. 125 introduce two or three small cones with lava flows, similar to that in Fig. 126, but differing in shape and position. Represent lakes in appropriate places with their elevations.

Exercise 2. On Fig. 127 cut off the front of the block along KK' to show structure of lava flows.

Exercise 3. Using three, four, or more colors, tint the lava flows in Figs. 126, 127, and 128, so that the corresponding lava flows in each figure are similarly colored. Color both surface and cross-section.

Exercise 4. Using Fig. 131 as a guide, prepare several little sketches showing Cinder Cone as it would appear in successive positions to one flying over it.

Exercise 5. Color Fig. 131, using pale blue for the lakes, a light green for the hills beyond the valley, a very faint blue or green for the most distant hills, a bolder green or brown for the foreground, and gray for the lava flows.

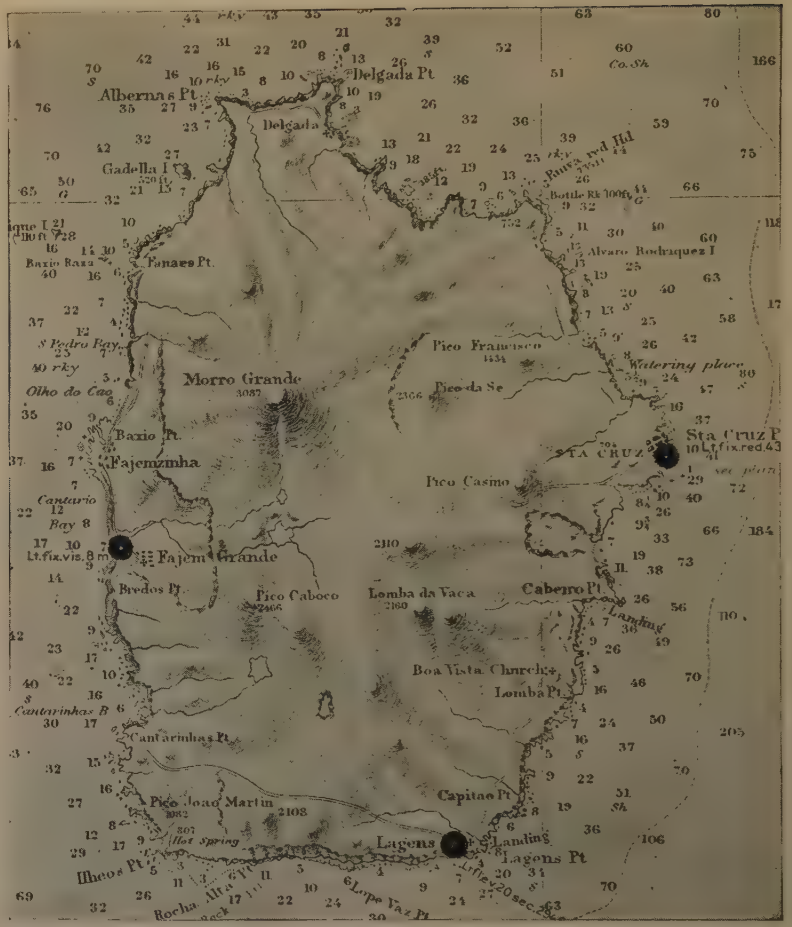


FIG. 133.—Map of Flores, Azores Islands, from U. S. Hydrographic chart. Volcanic cones without craters.

Exercise 6. Prepare bird's-eye views of Corvo (Fig. 132) and Flores (Fig. 133), selecting the points of view most appropriate in each case.

Exercise 7. Prepare block diagram of Crater Lake, using Crater Lake National Park sheet, Oregon, and Professional Paper No. 3.

CHAPTER X

STREAMS

90. Young, mature, and old streams: a definition.—A young stream is a stream whose capacity to transport a load is greater than the load it is called upon to carry. A mature stream is one that is loaded to capacity. When a stream has a steep gradient, and therefore a swift current, it usually carries its load of sediment with great ease and has enough energy left over to erode its bed and thus deepen its valley. Such a stream is young and its valley is usually V-shaped and narrow, and its course is characterized by cascades and waterfalls, potholes, and other evidences of vigorous erosion. When a stream has a gentle gradient or is overabundantly supplied with mud and silt by its tributaries, it uses up all its energy in carrying along this load, and instead of cutting down its channel it occasionally must deposit some of its load when temporarily there is brought to it more than it can remove. Such a stream is said to be mature, and its valley is usually wide and flat, owing to the floor of alluvium which the stream, in its meandering, has deposited on its flood plain. When such a mature stream is deprived of its usual load of mud through any change in the behavior of its tributaries, it ceases to deposit and, owing to its excess energy, it cuts down into its flood plain which it proceeds to remove, leaving only remnants here and there along the valley wall as terraces. Such a stream is said to be revived or rejuvenated.

If a river system so wears away the land that there are no hills left in its drainage area and all its tributaries are like it in flowing over a low plain, the river is said to be old. That means that it is carrying almost no load. Its gradient is so gentle it can just barely flow along without having to transport any material. Its tributaries are like it, even to their headwaters, and because of their slight energy they bring little or no debris into the main stream. Needless to say, this condition is perhaps never reached by large river systems whose headwaters must usually be found actively at work among the mountains surrounding the drainage basin. None of our large rivers, then, have passed beyond the mature stage.

91. Young streams: the V-shaped gorge, steep gradient and irregular bed with rapids and waterfalls.—When this subject is first presented to young students the teacher will add much life to his demonstration if he build up the situation on the blackboard in the manner shown in Figs. 134, 135, 136, and 137. First, draw the V-shaped cross-section of the stream. Then, after that has been duly discussed, build out the topography back of it. The figures indicate some of the intermediate steps which will be found helpful in a hurried blackboard illustration. The time consumed in preparing such sketches is an important item and usually should not exceed a minute. Sketches like Figs. 134, 135, 136 and

137 can easily be prepared in half that time, unless the teacher stops for a discussion, a thoroughly commendable practice.

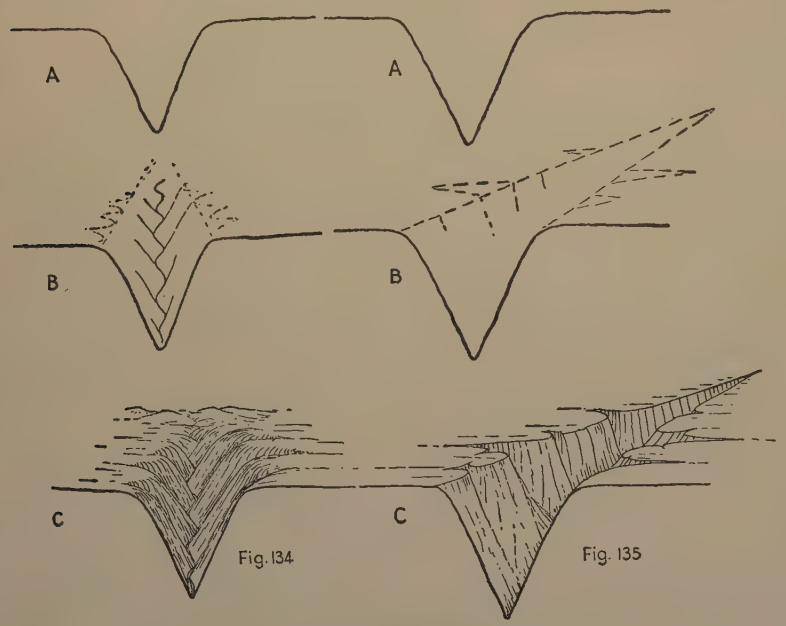


FIG. 134.—Steps of procedure in drawing a young stream valley. First, the V-shaped cross-section shown in *A*. Second, the wavy course of the stream with spur profiles tangent to the curves of the stream. Also faint guide lines for general form of valley, shown in *B*. Finally, in *C*, the completed sketch. Discussion of this region would include the erosive work of young streams, their winding course, the interlocking spurs, and valley widening due to weathering. This might be followed with a remodeling of this drawing on the blackboard to show later conditions as the valley becomes wider.

FIG. 135.—Steps of procedure in preparing sketch of young valley with V-shaped cross-section. A sketch like this may then be remodeled to show structural control due to horizontal beds of hard rock.

92. The profile of a young stream.—The gradient of a young stream, as indicated by its profile, may be explained by some means such as those used in Figs. 140, 141, 142. In Fig. 140 the teacher first puts on the blackboard the sloping curve representing the rather steep course of the young

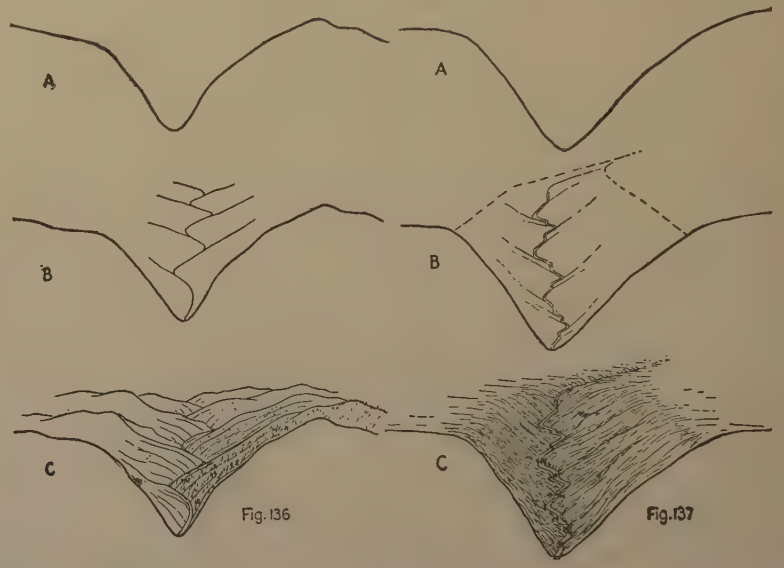


FIG. 136.—Steps of procedure in preparing sketch of young valley in rugged region, with a little suggestion of forest cover on the mountain sides to gain effect of distance.

FIG. 137.—Steps of procedure in preparing sketch of young valley with stream having falls and rapids. Draw first the V-shaped cross-section *A*. Then the winding course of the stream, exactly like *B* of Fig. 134 or 136, but interrupt the straight stretches of the stream with steps to represent vertical descents or falls, as in Fig. 138. Discussion of the completed sketch may include questions of rock structure, reaches and rapids, potholes, retreat of falls, valley widening, and development of the graded profile.

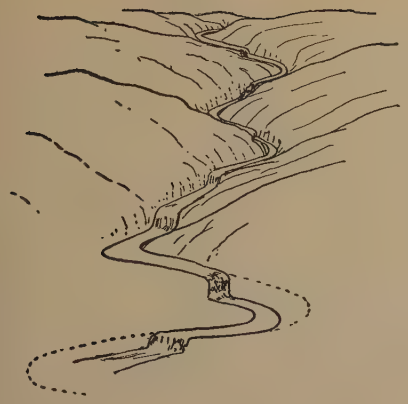


FIG. 138.—A sketch similar to Fig. 137 but showing a little more distinctly the way the swinging curves of the stream are modified to allow for falls.

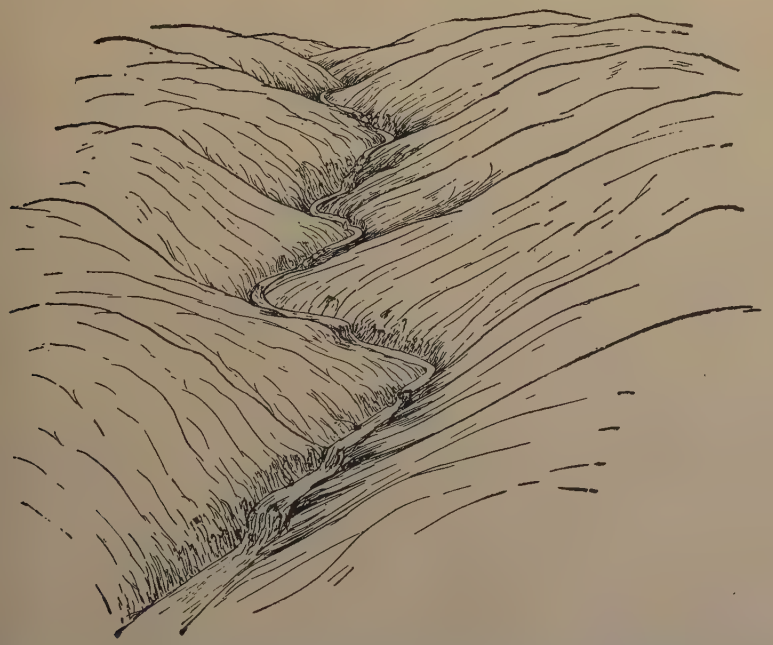


FIG. 139.—A valley similar to Fig. 137 but without the cross-section in the foreground. A little freer and perhaps a more natural handling of the problem.

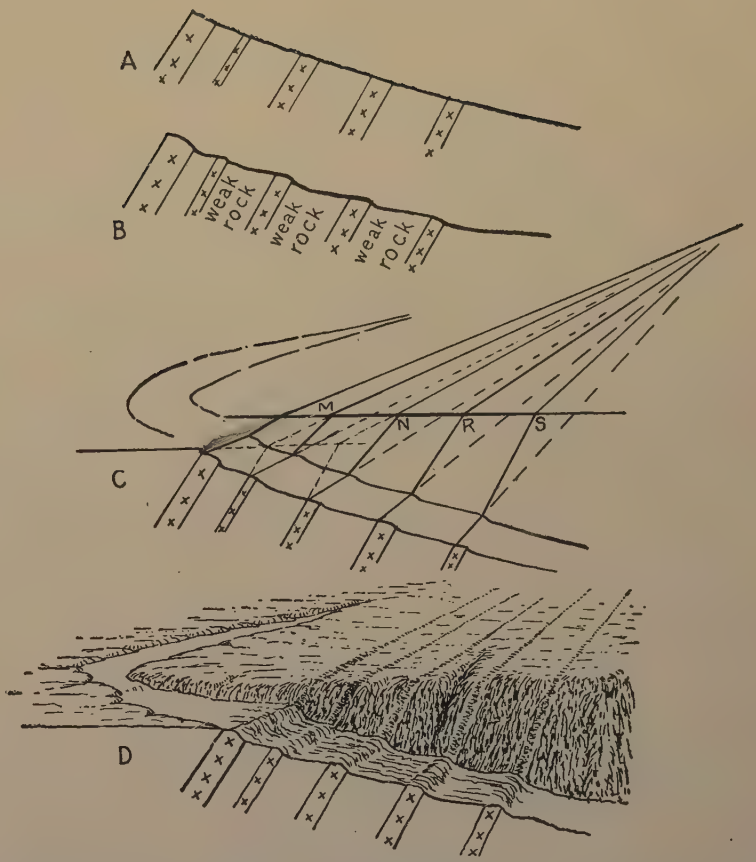


FIG. 140.—Steps of procedure in preparing sketch of young valley seen from the side in order to show stream profile with rapids due to hard ledges. Sketch *C* shows use of vanishing point and indicates how the positions of the points *M*, *N*, *R*, and *S* are obtained.

stream. After this is discussed he suggests that the stream may be flowing over hard ledges of rock which outcrop in its bed, as shown in *A* of Fig. 140. Because the stream wears away the weaker rocks it comes to have an irregular profile as shown in *B*. With this new profile as a starting point the block is built up in the manner shown in *C*, and the sketch finished by shading, as in *D*.

FIG. 141.—A sketch similar to Fig. 140 but handled somewhat differently. For instance, the observer is below the highest parts of the landscape.

Discussion of this drawing would bring out the fact that the falls and rapids retreat very little upstream, but tend rather to wear away, and that each hard ledge acts as a temporary base-level for the reach of the stream just above.

Or the profile shown in *A* of Fig. 142 may be used as a starting point. In this case horizontal formations outcrop in the bed of the stream. Upon profile *A*, Fig. 142, the sketch shown in *B* may be built. Discussion of this situation would consider the retreat of the falls upstream in the manner shown by the tributary gorge working back into the plateau. Another method of representing retreat of falls upstream is suggested in Fig. 143.

93. Young gullies and alluvial fans.—The habits of young streams may very happily be introduced by calling attention to the gullies which can be seen on ploughed hillsides. Many

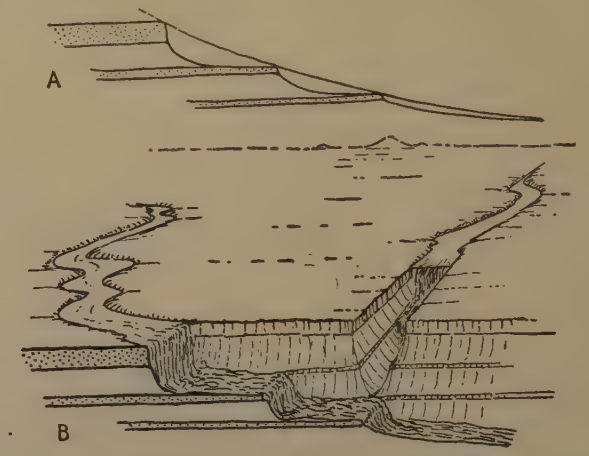


FIG. 142.—Profile of young stream, *A*. This is drawn first and then the background is built upon it as in *B*. In this case the falls retreat upstream and do not wear down as in Fig. 140.

students already realize that these gullies tend to become longer by eating headward into the hill and that they gradually develop intricate systems of tributaries in the same manner; and also that the soil thus removed from the hill may be found at its base in fan-shaped deposits. Fig. 144 may suggest the method of presenting these facts.

94. Young stream notch across tilted hard formation.—Many streams flowing across folded and tilted rocks have graded their courses across the hard formations and flow through water gaps marked only by a few riffles rather than

by distinct falls. In such cases the form of the notch, as it might be shown on a topographic map, gives a clue to the rock structure. As one follows such a notch down the dip of the formation, the notch becomes narrower and steeper-walled, though not so deep. This is illustrated in Fig. 145, which incidentally provides an excellent subject for a neat contour map. This is required in the exercises at the end of this chapter.

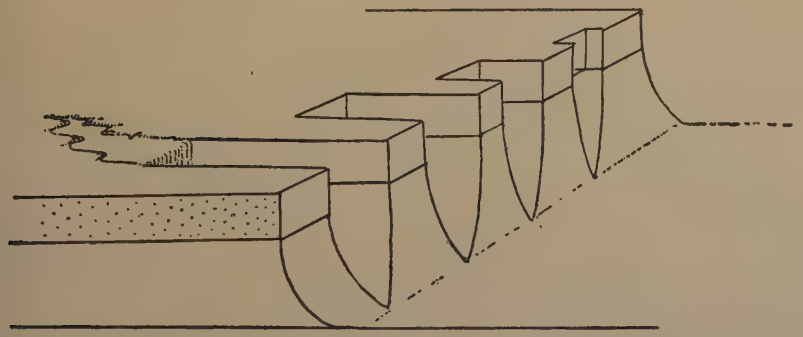


FIG. 143.—Retreat of falls upstream. An easy drawing to prepare for blackboard use to show one way in which a gorge may be formed.

95. Stream capture.—The different steps in the process of stream capture may be represented by a series of drawings, or by a single drawing such as has been attempted in Fig. 146, which is described in its accompanying legend. While a drawing like Fig. 146 has the advantage of being much more compact than several drawings would be, yet to some extent it may be confusing in not separating the stages distinctly from each other. Fig. 147 represents a situation where stream capture is imminent. The representation of the later stages is left as a problem for the student.

96. Specific example: the narrow valley of a young stream; Hawley sheet, Massachusetts.—In Fig. 148 a part of the Hawley sheet is shown. The Deerfield River has cut a gorge below the surface of the New England upland, and is a good example of a young stream. The shaded technique used in this drawing makes it less formal in appearance than those drawings which depend upon harsh lines. It approximates somewhat the appearance of a blackboard sketch.

FIG. 144.—A two-minute sketch for blackboard use to illustrate the development of gullies and alluvial fans on hillslopes.

Let us make an observation or two upon it. First of all, it is to be noted that the form of the stream does not always permit the curves to be flattened out in order properly to produce the effect of foreshortening. This is a defect which can be only partly remedied. The best thing to do is to effect a compromise between a representation of the stream as it actually is and the ideal representation of a stream with very regular curves. In the second place, it should be noted that, although the profile lines of the spurs have not been drawn in sharply, as in the previous figures, nevertheless their pres-

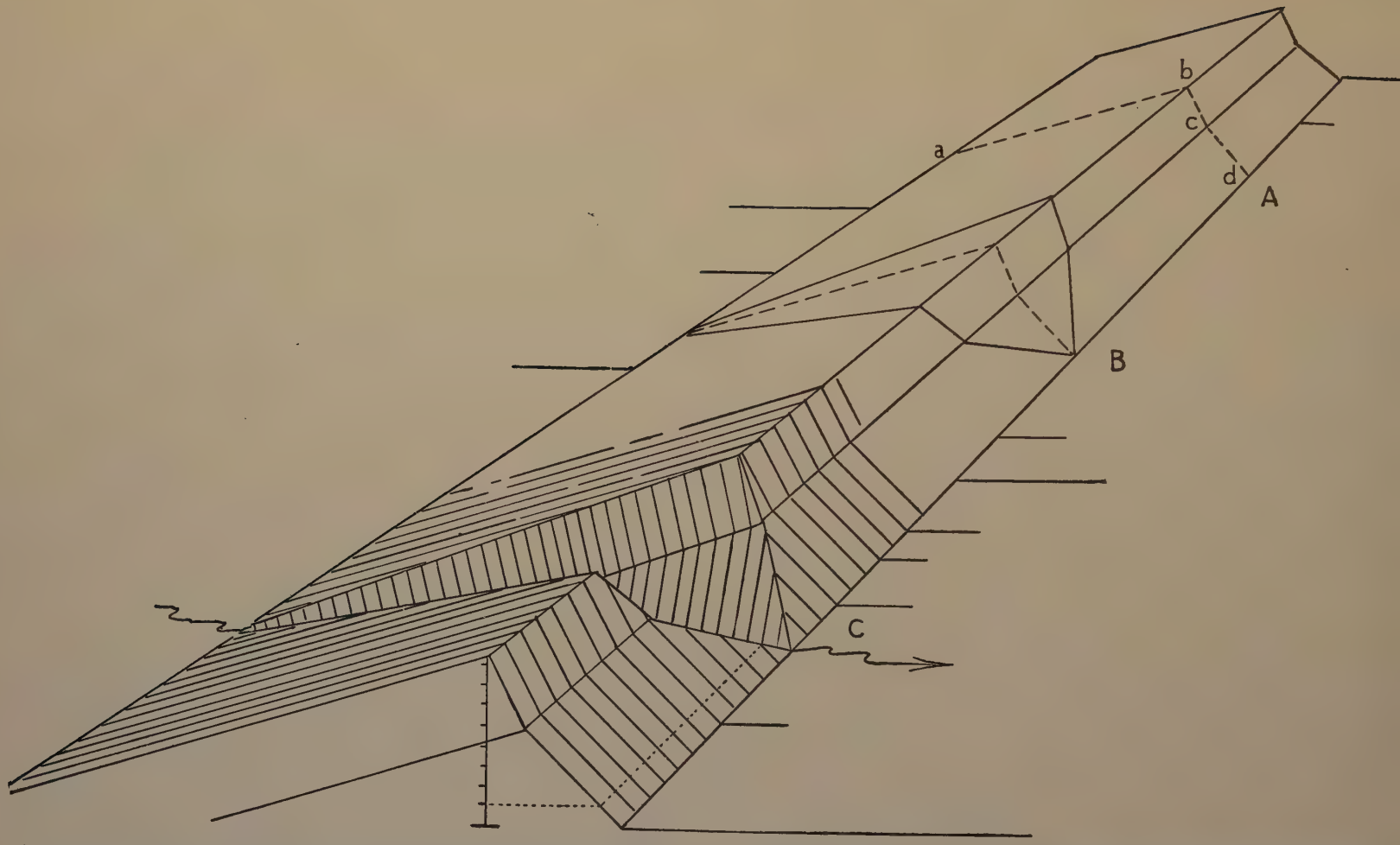


FIG. 145.—Stream notches cut across a tilted hard formation. Method of drawing the notches suggested by the stages *A*, *B* and *C*. In the front cross-section a vertical scale is introduced to aid in representing the position of contour lines. The lowest contour line is partly expressed by a dotted line.

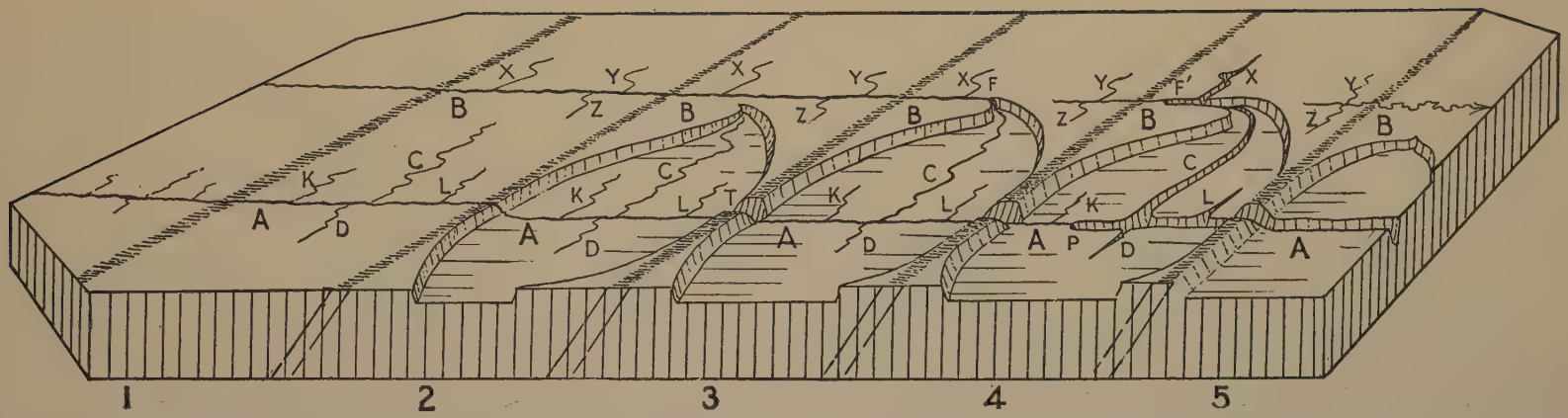


FIG. 146.—Block diagram to illustrate several stages in the process of stream capture. In section 1 we note two streams *A* and *B* flowing across alternating hard and soft formations. In section 2 we find that stream *A* has shown its superior strength by cutting across the hard ridge at *T* and that its tributaries *C*, *K*, *L*, and *D* have thereby been enabled to cut out quite a valley in the weaker formation. In the next stage, at 3, we see that tributary *C* has worked headward still farther and has just captured stream *B*. The 4th stage shows some of the later effects of capture. The increased volume of stream *C* has caused it to cut a deeper channel. Similarly the lower course of stream *A* has been rejuvenated. The effect of rejuvenation is felt by the tributaries *L* and *D* and the upper part of stream *A*, all of which are now able to cut deeper. The falls shown at *F* in section 3 have retreated upstream to the point *F'*, thus enabling stream *X* to deepen its channel. The falls at *P* are likewise working upstream. In section 5 we see the lower course of stream *B*, now a beheaded stream, dwindled in volume and meandering in its channel. Its tributaries *Y* and *Z* are undoubtedly overloading it with sediment.

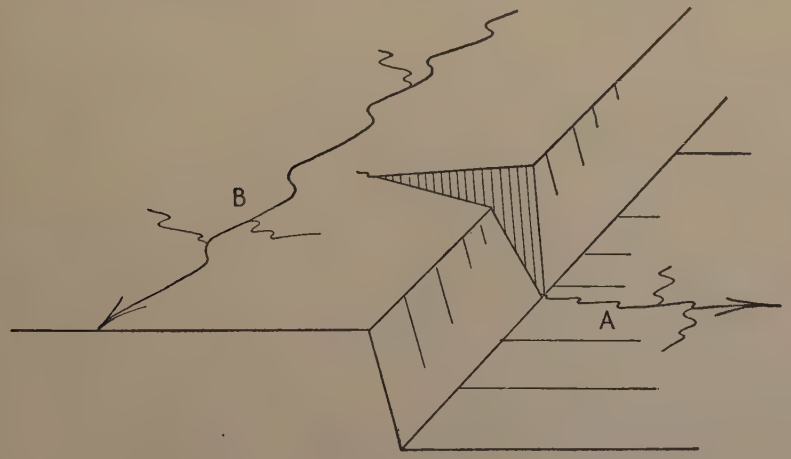


FIG. 147.—Imminent stream capture. Stream *A*, flowing upon the lower level, is working headward into the upland and is about to capture the headwaters of stream *B*.

ence is felt when the shading is being done. Thus, even in a shaded drawing of this kind which serves so well for blackboard illustration, the principles already developed are applied.

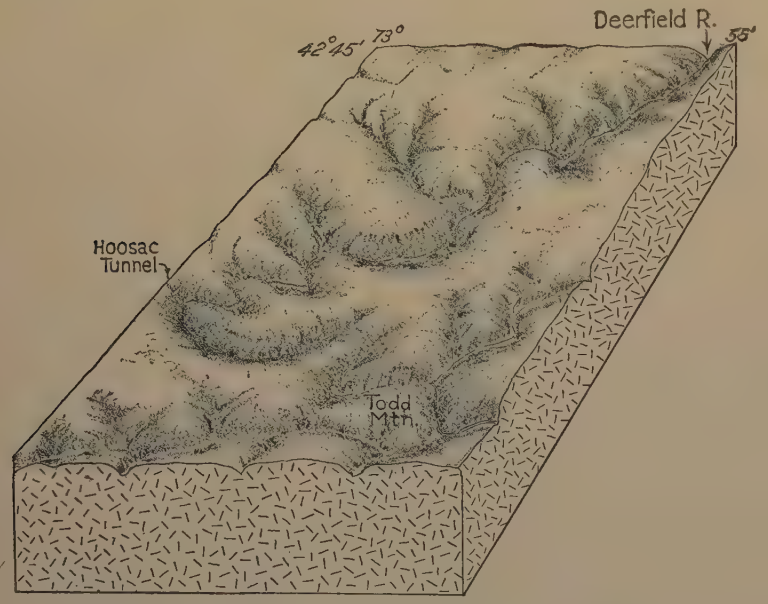


FIG. 148.—Block diagram of part of Hawley sheet, Mass., showing the narrow youthful gorge of the Deerfield River which has cut below the level of the New England upland. A sketch similar to this might readily be prepared for blackboard use, the handling of the chalk being more or less suggested by the technique used here.

97. Specific example: retreat of falls; Niagara Falls sheet, New York.—In Fig. 149 a part of this area is blocked out in a rough and ready manner, to suggest one method of attacking such a problem when a bird's-eye view is desired. Details of topography, culture and geological cross-sections can readily be introduced.

98. Mature streams: the wide, flat valley floor.—It was pointed out in Section 90 that mature streams have graded

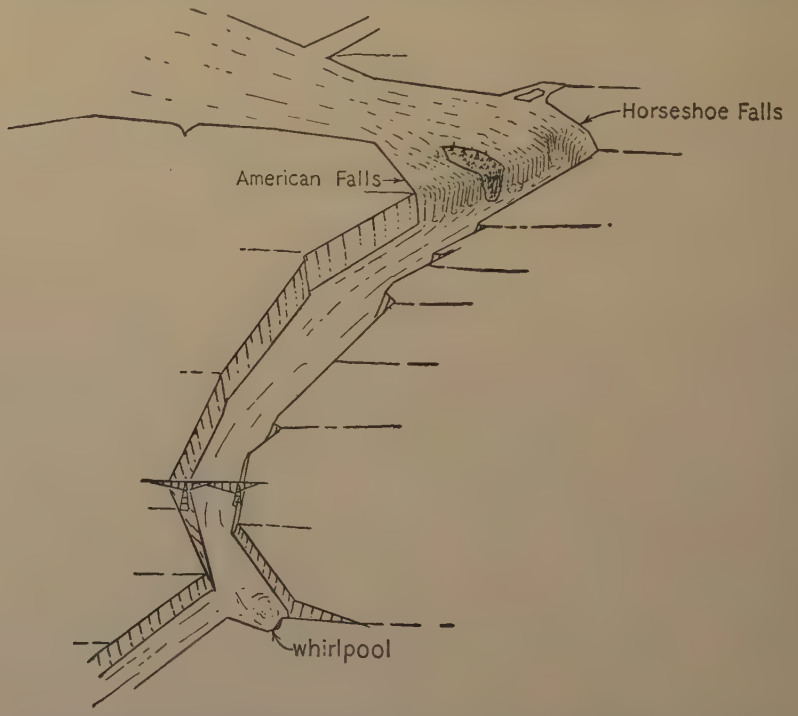


FIG. 149.—Sketch of Niagara Falls region from Niagara Falls sheet. Cross-sections may readily be added to a drawing of this type where it is desirable to show rock structure of the plateau.

courses. That is to say, their slope just enables them to transport the load which they are bearing. While such a stream may have a narrow valley and still conform to this

definition, usually mature streams have had time to widen out their valleys. During this time weathering has probably reduced the slopes of the valley walls to a gentle angle. The transition from the conditions of youth to those of maturity are very well expressed in Fig. 150 by W. M. Davis. Study this sketch and note how well, and at the same time how simply, it shows the widening valley floor and the gentler slopes of the valley walls in the later stages. In stages *A* and *B*, rock outcrops along the valley walls are common, but in the later stages the slopes are well graded and have a deep soil cover. Analyze this drawing now and note that it is exactly like others which have been described. It is drawn in two-point perspective. Fig. 151 shows the relation of Fig. 150 to its vanishing points. The larger drawing shows nothing in addition to the smaller one. Consequently the corners are trimmed off in order to produce the convenient rectangular drawing reproduced in Fig. 150.

99. Specific examples: mature streams; New Orleans, La.; Northampton, Mass.; Millikin, La.; Vicksburg, Miss.; Germany, 1 : 100,000, Landau sheet, No. 572, Karlsruhe sheet, No. 573, Rastatt sheet No. 588; Hungary, 1 : 75,000, Kistelek und Szeged sheet, No. 5464.—The drawing of the various details of topography associated with mature streams will probably not afford any especial difficulty to the student who has pursued the work thus far. The following maps will be found exceptionally interesting in affording suitable problems. The New Orleans sheet, partly worked out in Fig. 152, illustrates the large meanders and natural levees of the Mississippi River. The Northampton sheet presents an interesting case of a meander cut-off on the Connecticut River. The drawing, Fig. 153, helps to explain the position of the meander by showing how the downstream migration of the meander was held back by the Holyoke Range. On the Millikin sheet may be seen one of the neatest examples of an ox-bow lake formed by a cut-off. The natural levees are distinctly shown too. The Vicksburg

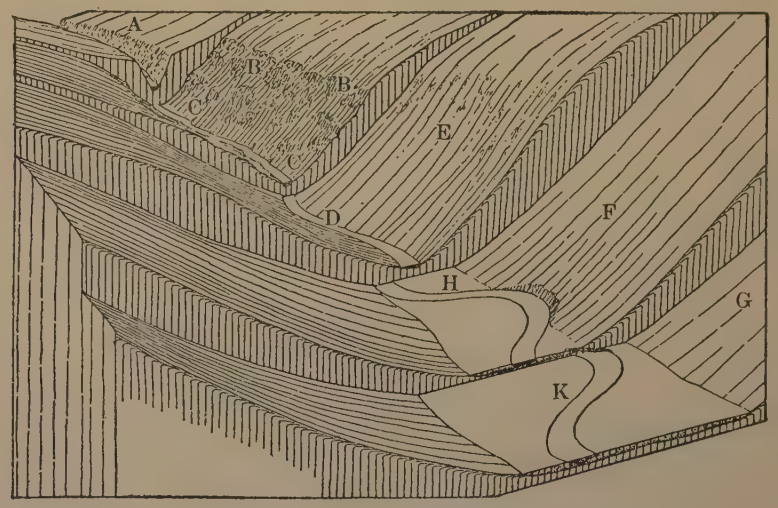


Fig. 150.—Transition conditions shown in stages from young to mature valley. The young stages, *A* and *B*, show narrow valley with steep walls and rock outcrops. The mature stages, *H* and *K*, show the wide, flat-floored valley with gently sloping valley walls and no rock outcrops. An analysis of the construction of this drawing is given in Fig. 151. (After W. M. Davis.)

sheet shows how the Mississippi River formerly flowed past Vicksburg, but by a cut-off the city is now left more or less away from the main channel. The Rhine River, pictured on the German maps, has a flood plain scored by many old meander channels with numerous remnants of the former river still present. The Theiss River in Hungary, shown on

the Hungarian map, is very much like the Rhine, but artificial straightening of its course has not been carried so far.

100. Drowned rivers and rejuvenated rivers.—In order to demonstrate the idea of drowning or submergence of a river valley, it is well to represent first the normal valley, and then later convert it into an estuary. It is helpful, too, if the position of contour lines is indicated on the valley walls. Each contour line may then be used to represent successive positions of the shore as the sea is brought in. Figures 154, 155, and 156 fully explain this procedure.

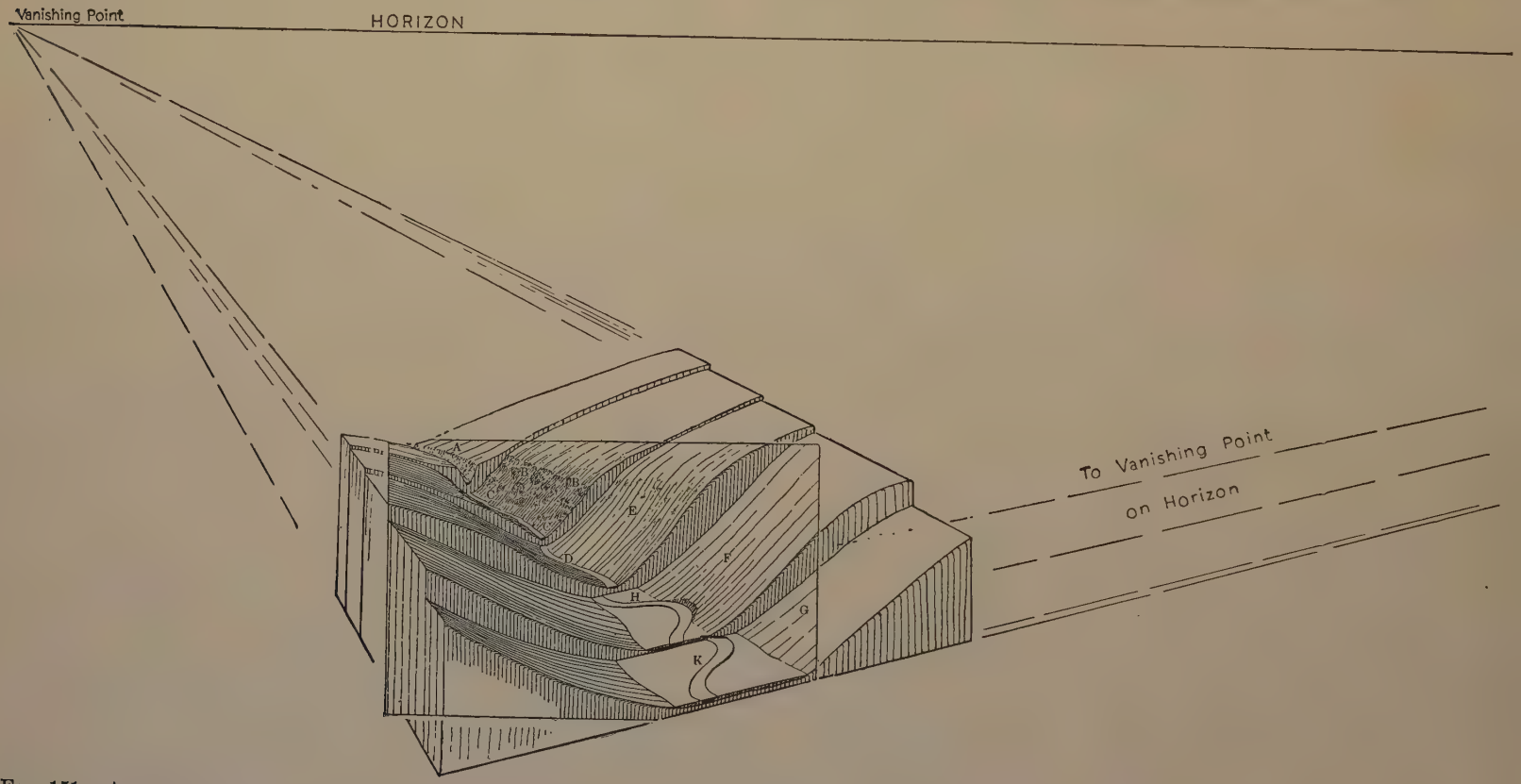


FIG. 151.—An extension of Fig. 150 to show use of vanishing points on the horizon. The several blocks are completed. The complete drawing is no more useful than the other and is far less compact. In the preparation of Fig. 150, however, the complete blocks would first be prepared in accordance with the method shown in this figure.

FIG. 152.—Block diagram of part of New Orleans quadrangle, Louisiana, showing some of the characteristics of a mature river, chief of which are the natural levees.

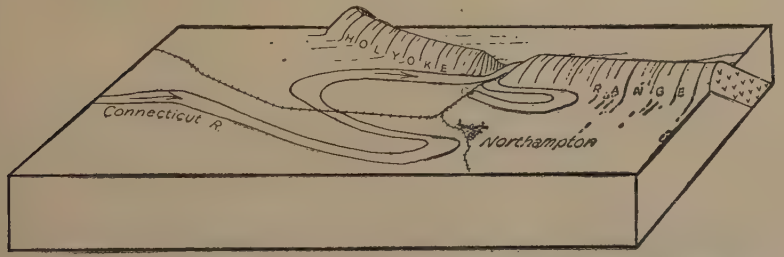


FIG. 153.—Block diagram of part of Northampton quadrangle, Massachusetts, showing cut-off meander due to the barrier of the Holyoke Range which prevented the down-stream migration of this meander.

FIG. 154.—A shallow valley in a plain with one contour indicated near its upper part. If submergence of this valley occurs the resulting estuary is broad with many wide embayments, not so narrow and fiord-like as the one shown in Fig. 156.

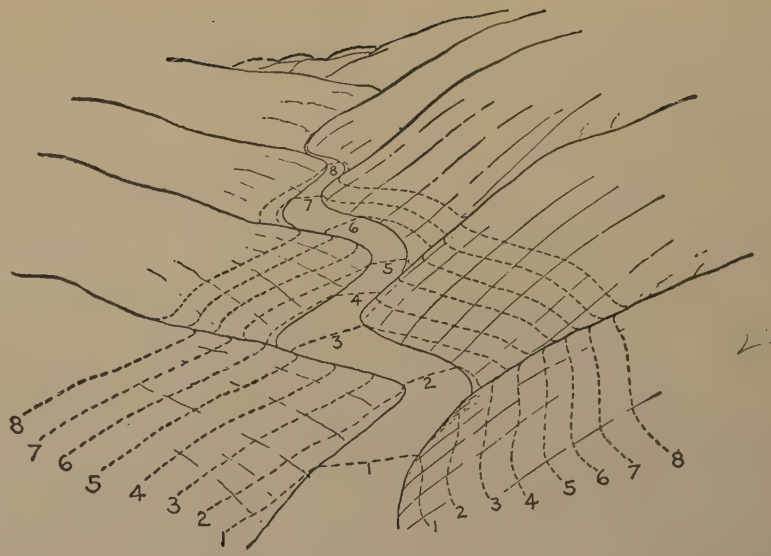


FIG. 155.—A narrow valley in mountains with the position of contour line shown on the valley walls.

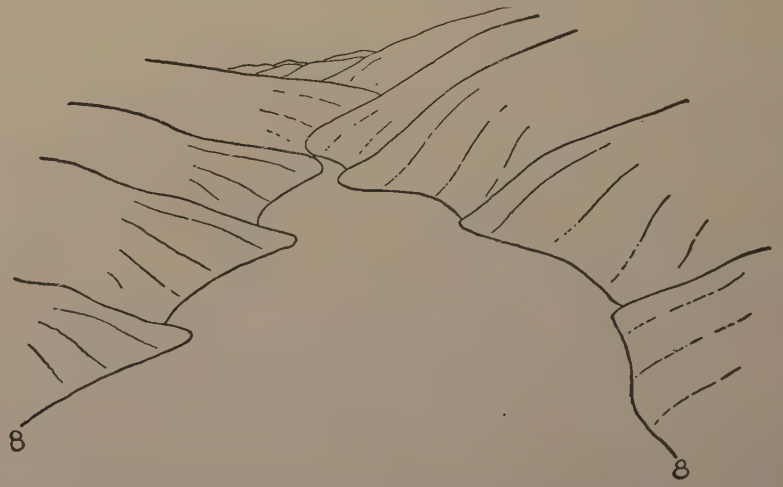


FIG. 156.—The valley shown in Fig. 155 has been submerged to the height of the eighth contour, forming a long, narrow estuary.

The representation of rejuvenated streams as exemplified by the development of stream terraces will be best accomplished by referring to the very excellent illustrations by W. M. Davis accompanying his article on river terraces in New England, to be found in his Geographical Essays.

EXERCISES

Based upon the Illustrations in Chapter X

Exercise 1. Complete part *B* of Fig. 134 to resemble part *C*.

Exercise 2. Complete part *B* of Fig. 135 to resemble part *C*.

Exercise 3. Redraw as much as necessary of Fig. 135, *C*, to show effect of outcropping layer of hard rock about midway up on the valley walls. Show this layer in the cross-section too.

Exercise 4. In Fig. 136, complete sketch *B* and show trees on both sides of the valley.

Exercise 5. In *A* of Fig. 137, draw course of stream with waterfalls and complete sketch to resemble *C*.

Exercise 6. In *A* of Fig. 137, draw course of stream showing one large waterfall about midway back in the view, with narrow V-shaped valley above and below the falls. After completion of the sketch represent on it the position of contour lines, selecting a convenient contour interval so that about twelve contours will be required. Then draw map of the region, representing the same contours seen from above.

Exercise 7. In Fig. 140, sketch *C*, explain how the positions of the points *M*, *N*, *R*, and *S* are obtained. Draw another sketch similar to *C* and show the appearance of the outcrops of the hard formations if the valley were strictly vertical; and again if the valley were widely flaring at the top so that the valley wall had a very gentle slope. (Make these sketches large so that all construction lines may be distinctly shown.)

Exercise 8. Upon sketch *A* of Fig. 142, build a plateau similar to sketch B. Show all construction lines in the manner of sketch *C* of Fig. 140.

Exercise 9. Complete notch *B* in Fig. 145. At *A* in Fig. 145, using the line *abcd* as a medial line, represent another notch like that shown at *B* or *C*. At *C*, Fig. 145, draw contour lines upon the block in the manner already shown for the lowest one, the contour interval being indicated by the scale at the front of the drawing. Show contours in the notch and on the back slope. Show the construction lines necessary to determine the position of contours on the wall of the notch.

Exercise 10. Draw a contour map of the notch shown at *C* in Fig. 145, being careful to represent all the planes and their relative slopes.

Exercise 11. Draw similar contour map of young notch in tilted hard formation but with stream flowing in the same direction as the dip of the formation.

Exercise 12. Extend Fig. 144 to the left and show further development of the gully. Most of the hillside should be eaten away. Here and there a few remnants, like miniature buttes and mesas, should be left between the tributaries.

Exercise 13. Prepare a contour map of each of the gullies shown in Fig. 144, together with its alluvial fan.

Exercise 14. Change Fig. 146 so that section 1 resembles section 2; section 2 resembles section 3; and section 3 resembles section 4.

Exercise 15. Prepare a series of drawings to illustrate several stages in the process of stream capture, using Fig. 147 as the first stage.

Exercise 16. Redraw all or part of Fig. 148, using definite lines instead of shading.

Exercise 17. Prepare a simple sketch of the Hawley region, shown in Fig. 148, as if seen from a much lower level so that the river is nowhere visible.

Exercise 18. Add one block to the foreground of Fig. 150, using vanishing points as in Fig. 151.

Exercise 19. Prepare a drawing showing the appearance of the valley in Fig. 154 after it has been submerged to the level indicated by the dotted contour line.

CHAPTER XI

GLACIERS

101. Glacial cirques.—Of all the forms to be seen in landscapes, those produced by glaciers in mountains are the most difficult to draw. These forms, however, may all be analyzed, and it will be found that most of them can be resolved into cones, cylinders, or spheres. The cirque is essentially the inside of an inverted cone. This is easy enough to draw if the cone is cut out of a flat surface as shown in part 1 of Fig. 157. The intersection of the cone with the horizontal plane is a circle which appears in perspective as an ellipse. If, however, the surface cut by the cone is made up of two planes, as in part 2 of Fig. 157, then the intersection consists of parts of two ellipses attached to each other. In part 3 the two ellipses join at a little sharper angle. In part 4 of Fig. 157 three ellipses are used to represent the intersection of the cone with the surface of the ground, and in part 5 the same general form is expressed with more freedom and is intended to represent the appearance of a cirque on a gently sloping mountain side.

Instead of the cone, the cylinder may be used to determine the form of the cirque and very little difference between the two will be noted. In Fig. 158 the intersections of cylinders with a spherical surface are shown. While these intersections have been worked out geometrically with a little care, in actual practice the student is not expected to bother with any refinements, provided he note now one or two things regarding the shape of the ellipse-like outline on the

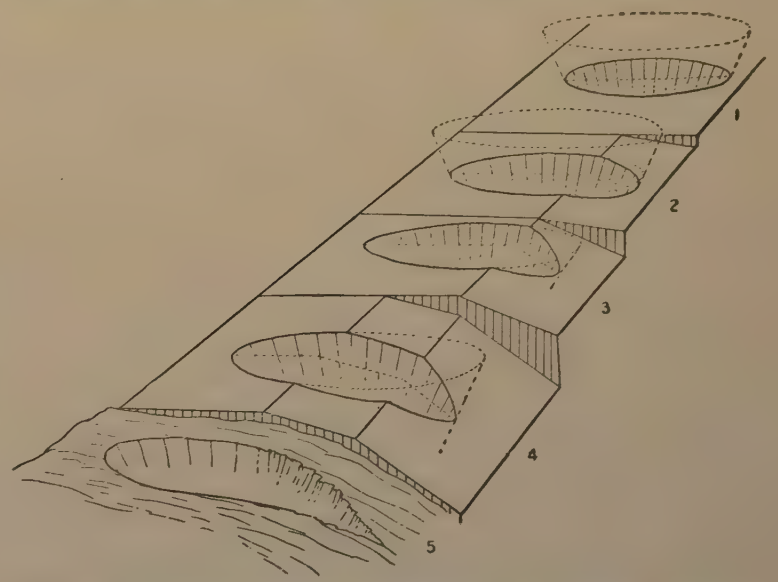


FIG. 157.—Series of drawings to show application of the inverted cone in drawing cirques. More completely explained in Section 101 of the text.

surface of the sphere. These so-called "ellipses" are placed symmetrically with respect to the medial lines OL and OK

which pass through the axes of the cylinders. But in the illustration the distance AB appears greater than AC. This is owing to the fact that the nearer space AB is on a part of the sphere which is more nearly transverse to the line of sight than is AC which runs almost in the direction of sight and is consequently much foreshortened. If this general effect is obtained, therefore, little attention need be given to the actual development of these geometrical forms.

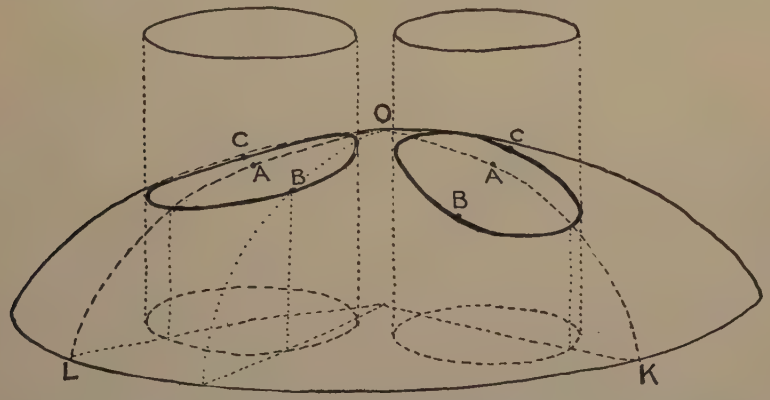


FIG. 158.—Application of the cylinder in drawing cirques on a spherical mountain mass. To show that in each case the distance AB from the meridional line appears longer than the distance AC.

In Fig. 159 several cirques are represented. The form of the cirques is patterned after Fig. 158. For instance, cirque X is placed symmetrically with respect to the meridional line OL and the distance AB is made greater than AC. When two cirques intersect each other a narrow arrête or ridge is formed between them and this constitutes a divide which is lower than elsewhere around the rim of the cirque. Such an arrête is shown between cirques X and W, and between X and Y.

102. Young and mature cirques.—Young cirques are those which have not entirely eaten away the rounded mountain surface. Mature cirques are those which have eaten back so far as to leave none of the rounded mountain top. The three stages, shown in Figs. 160, 161, and 162, clearly illustrate this development. In Fig. 160 the cirques are small and few arrêtes appear. In Fig. 161 the increase in the size of the cirques has caused them to intersect each other so that arrêtes appear between them. Some of the

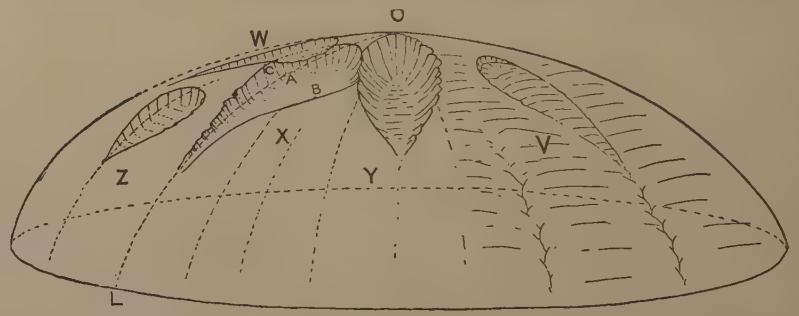


FIG. 159.—Cirques on a spherical mountain mass, drawn in accordance with the general form developed in Fig. 158.

smooth upland still remains. Hence this is called the submature stage. In Fig. 162 the upland is entirely consumed and has given way to sharp "matterhorn peaks." This is the mature condition.

103. Matterhorn peaks.—The drawing of peaks in a much glaciated mountain district is facilitated by the use of the pyramid as the most suggestive geometrical form. In Fig. 163 the four-sided pyramid is transformed into a matterhorn peak by introducing a cirque on each of its sides. Infinite variety may be obtained by changing the size and shape of the pyramid.

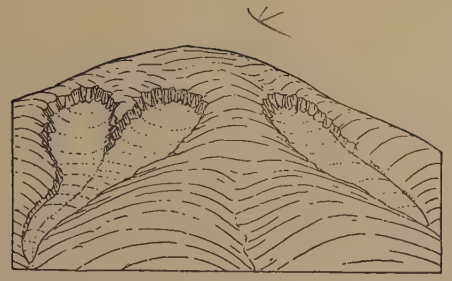


FIG. 160.—Young glacial cirques. Much of the rounded upland is still present. (From W. M. Davis.)

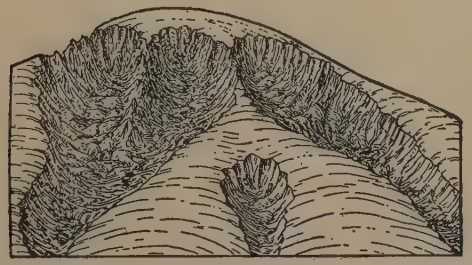


FIG. 161.—Submature glacial cirques. The upland has almost disappeared. (From W. M. Davis.)

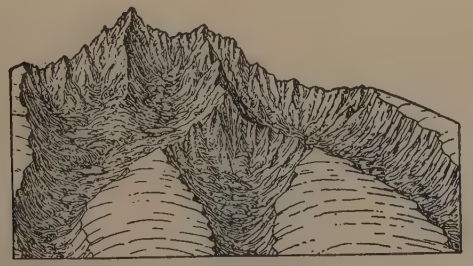


FIG. 162.—Mature glacial cirques. The upland has given place to matterhorn peaks and sharp-crested arrêtes along the divides. (From W. M. Davis.)

104. Glacial troughs.—Glacial troughs with hanging valleys may very readily be expressed by combinations of cylinders. These, with the addition of pyramids, can be made to resemble glaciated mountains. Figure 164 suggests one method of approach. Cylinders of different sizes may first be drawn and allowed to intersect each other at various

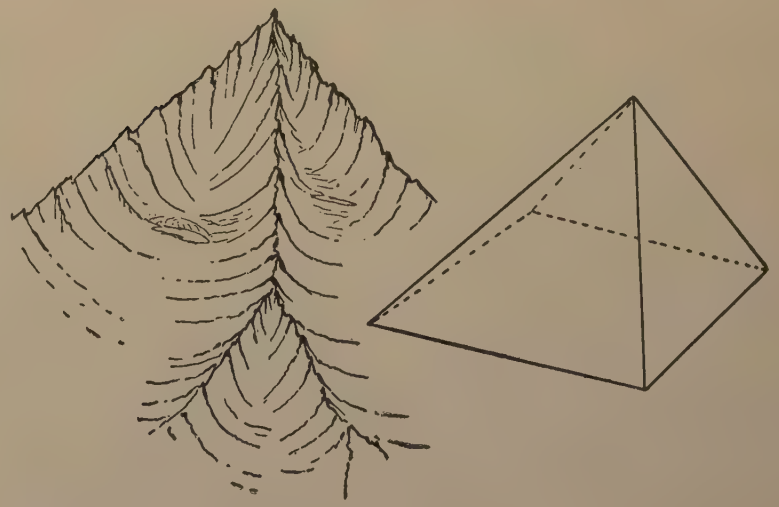


FIG. 163.—Application of the pyramid to the drawing of matterhorn peaks.

angles, according to the requirements of the problem. Numerous slight modifications may then be introduced after the situation is well in hand. For instance, the slope of the trough walls may be altered; the cylinders may be changed in depth at different places; they may be changed in shape so as to wind in great arcs like a gigantic canal between the mountains. Post-glacial notches, moraines, alluvial

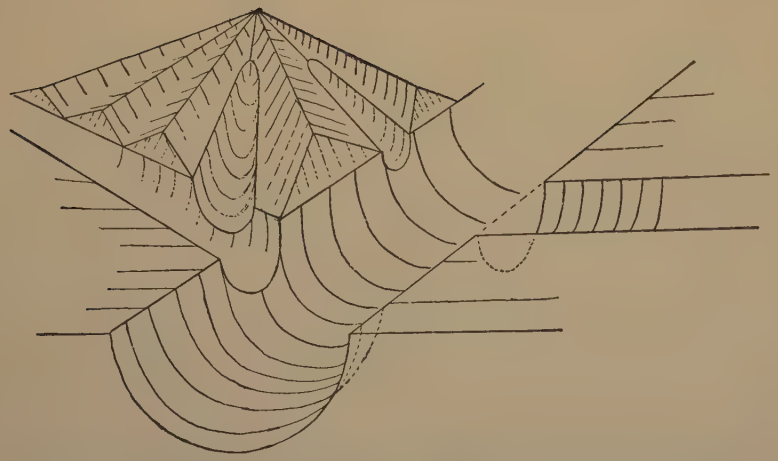


FIG. 164.—Application of the cylinder to the drawing of glacial troughs.

FIG. 165.—A normally eroded mountain mass, not affected by glacial erosion. (From W. M. Davis, by permission of Ginn & Co.)

fans, landslides, and lakes may be put in at appropriate places. The essential thing is to have a nice scheme blocked out in a simple clean-cut fashion. Examine Figs. 165, 166, and 167, and see how this method has been followed, to some extent, by Professor Davis, in developing glaciated

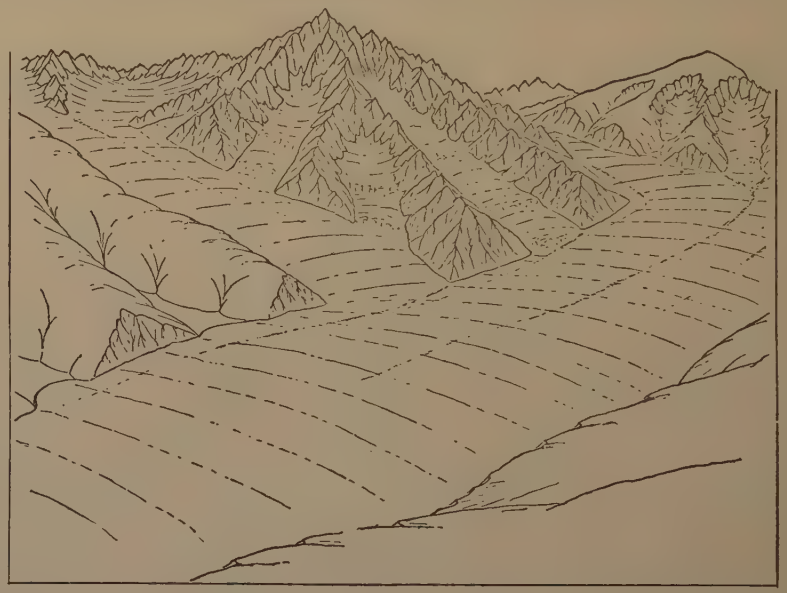


FIG. 166.—The same mountain mass as in Fig. 165, strongly affected by glaciers which still occupy its valleys. (From W. M. Davis, by permission of Ginn & Co.)

forms from non-glaciated mountains. These three splendid drawings will repay careful study.

105. Specific examples: youth and sub-maturity; Mt. Washington sheet, New Hampshire; Nyack sheet, Montana; Snowdon sheet, Wales, No. 41, scale one inch to a mile, British Ordnance Survey.—The transformation of an actual map of a glaciated mountain mass into a block dia-

gram, bird's-eye view, or picture, is best accomplished by sketching at first the essential form of the mountain mass prior to glaciation. For instance, the Presidential Range of the White Mountains, shown on the Mount Washington sheet, may be blocked out as in Fig. 168, and then this simple

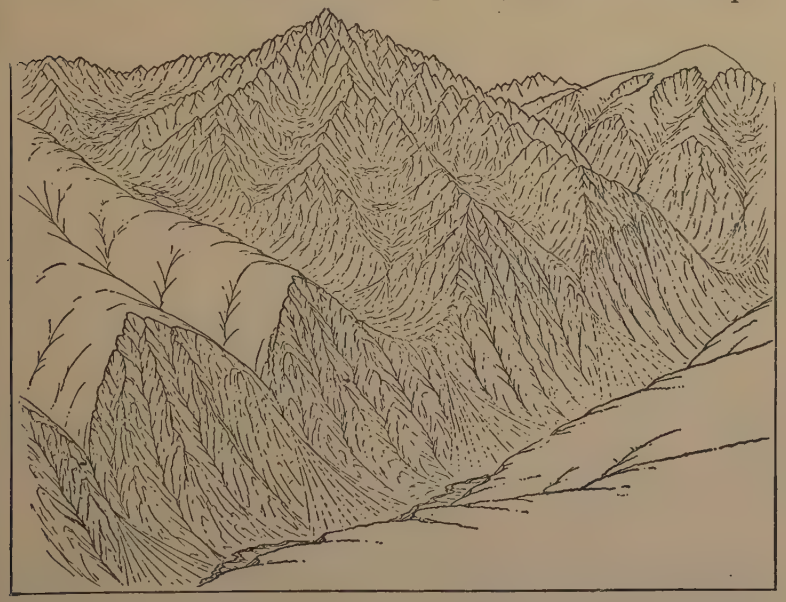


FIG. 167.—The same mountain mass as in Fig. 166, shortly after the glaciers have melted from its valleys. (From W. M. Davis, by permission of Ginn & Co.)

rounded mountain mass may be altered by the introduction of cirques and glacial troughs, as in Fig. 169, to represent the present stage of development.

The Mount Snowdon sheet presents a similar problem, and the transformation of all or part of this area into a bird's-eye view is left as an exercise for the student who has access to this map. Equally satisfactory is the Nyack quadrangle which shows the Flathead and Swan Ranges magnificently scalloped out with glacial cirques so as to produce the characteristic "biscuit-board" topography of submaturely glaciated ranges.

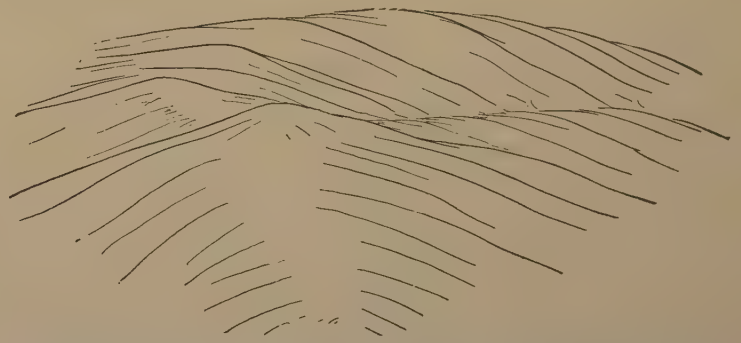


FIG. 168.—Rough sketch showing mass of Presidential Range before glaciation, as suggested by Mount Washington sheet.

FIG. 169.—The Presidential Range as it appears now. Rough sketch prepared by modifying the mass shown in Fig. 168.

106. Specific examples: mature glaciation; Chief Mountain sheet, Montana; Aletschgletscher sheet, Switzerland.—It becomes rather more difficult in the case of maturely

glaciated mountains, characterized usually by matterhorn peaks and sharp arrêtes, and with little evidence of an upland, to block out the initial form and then modify it to simulate present conditions. Instead of doing this, it has been found easier to block out the topography by establishing the position and shape of the peaks and arrêtes, and then filling in the details around these. Fig. 170 presents a hasty sketch done in this way from the Chief Mountain quadrangle. For blackboard illustrations this method should commend itself to the teacher.

Very complicated maps of maturely glaciated regions, such as those shown on many of the Swiss maps, may rather readily be transformed into bird's-eye views by the method explained in Section 127 and demonstrated in Figs. 216, 217, 218, and 219.

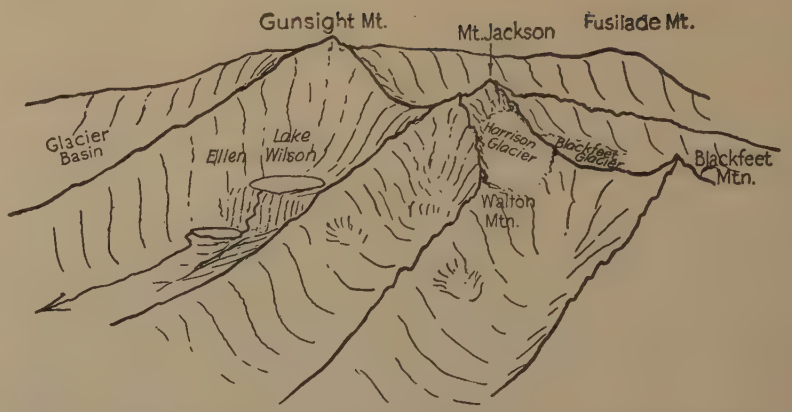


FIG. 170.—Simple two-minute sketch for blackboard use, drawn from Chief Mountain quadrangle, Glacier Park, Montana. View looking north, with no attempt at drawing to scale. The object is simply to block out the main features so that the peaks, cirques, hanging valleys, and rock steps may better be visualized by the class studying the map.

EXERCISES

BASED UPON THE ILLUSTRATIONS IN CHAPTER XI

Exercise 1. In Fig. 157, draw another cirque alongside of cirque 5 to show the shape of resulting arrête between the two cirques.

Exercise 2. Redraw Fig. 159, representing all the cirques as much enlarged by erosion, and show resulting arrêtes and matterhorn peaks.

Exercise 3. Redraw Fig. 161 with one of the cirques occupied by a glacier.

Exercise 4. Redraw Fig. 162 to show a later stage when the peaks have been worn much lower.

Exercise 5. Change the pyramid in Fig. 163 to resemble a matterhorn peak.

Exercise 6. Change Fig. 164 to resemble the features shown in Fig. 167.

Exercise 7. Show by construction lines how you would go about to change Fig. 165 to resemble Fig. 167.

Exercise 8. On Fig. 167 draw in a number of simple and usually straight construction lines to show application of cylinder and pyramid. (Tracing paper may be placed over the illustration for this purpose.)

Exercise 9. On Fig. 167 label the following physiographic features: glacial trough, hanging valley, young cirque, mature cirque, matterhorn peak, pre-glacial upland, arrête, tarn, rock step, post-glacial notch, alluvial fan, truncated spur, alp.

(Exercises Based upon Topographic Maps)

Exercise 10. Using the Mount Washington sheet and Fig. 169, prepare a bird's-eye view of the Presidential Range as seen from the north instead of from the south.

Exercise 11. Prepare a bird's-eye view of Mt. Snowdon, using the Mt. Snowdon map as the only source of information. Select the point of view which you deem most suitable.

Exercise 12. Prepare a bird's-eye view of part of the Nyack quadrangle.

Exercise 13. Prepare sketches, similar to Fig. 170, depicting other parts of the Chief Mountain quadrangle.

CHAPTER XII

WAVES

107. Shorelines of submergence.—The most pleasing effects in the portrayal of submerged coasts can best be obtained by first blocking out the promontories, making

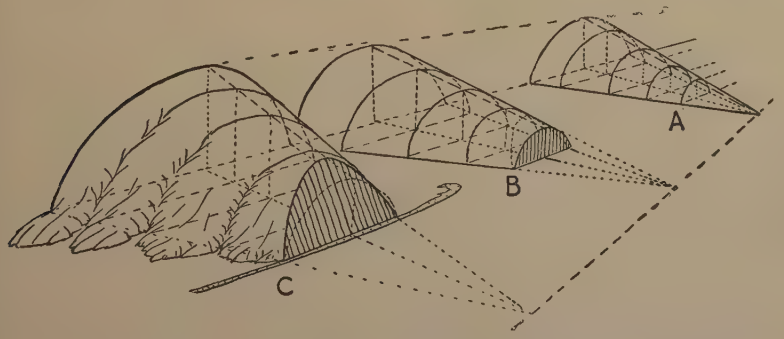


FIG. 171.—Application of the cone in representing the features of shorelines of submergence. Note suggestion of vanishing points far to the right and left. *A*, simple undissected cone; *B*, end of cone truncated to form vertical cliff which in *C* has been given a slant. Modifications in *C* suggest methods of introducing details.

use of the cone, as in Fig. 171. Half a cone, lying on its side, gives a strong resemblance to a promontory. The height may be modified by using a more sharply apexed cone or by using less than half a cone, so as to get a flatter top. A little ingenuity will enable the student to modify the cone, either by cutting off parts or by adding on bulges and protuberances to give the proper landscape effect. A systematic discussion of the features characterizing various stages of development along shorelines of submergence will be found in Johnson's "Shore Processes and Shoreline Development."

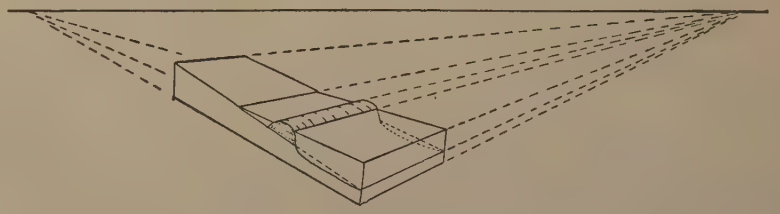


FIG. 172.—Simple block as a basis for portrayal of features developed on shoreline of emergence.

108. Shorelines of emergence.—The block used for shorelines of emergence is essentially the same as that used for the coastal plain, except that a greater proportion of the block must be devoted to the water area. A block of this type is shown in Fig. 172 with a simple barrier beach drawn in. This is one of the earliest stages in beach development. A succession of stages is shown in Fig. 173, taken from W. M. Davis, and presenting in a decidedly neat and compact

manner the succession of features developed from youth to maturity.

109. Specific cases: Weymouth sheet, No. 143, British Ordnance Survey, scale one inch to a mile; Monte Argentario, Italy.—In Fig. 174 two sketches are given, interpreting the Weymouth region. In one the observer is looking

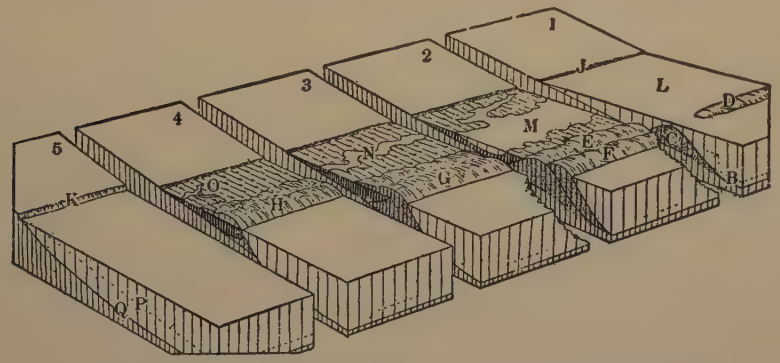


FIG. 173.—Series of stages from youth to maturity along a shoreline of emergence, showing first the initial offshore bar, followed in the second phase by a gradual filling of the lagoon and accretion to the bar on the outside. In the third phase the lagoon is almost filled and the bar is being pushed back on top of the lagoon muds. The shore profile is gradually changing as the waves cut into the ocean bottom. In stage four the barrier rests entirely upon the lagoon filling and in five the barrier and lagoon have been entirely removed so that the waves are cutting against the mainland. In stage five the difference between the original profile *P* and the new profile *Q* is plain. (From W. M. Davis.)

toward the east, in the other toward the west. Note the use of the ellipse in laying out these sketches. The ellipses which are nearest the observer, approximate a circle in form, whereas the ellipses farther away are flatter, and those most remote approximate a straight line. Even if the exact form of the coast is not thus represented, at least the

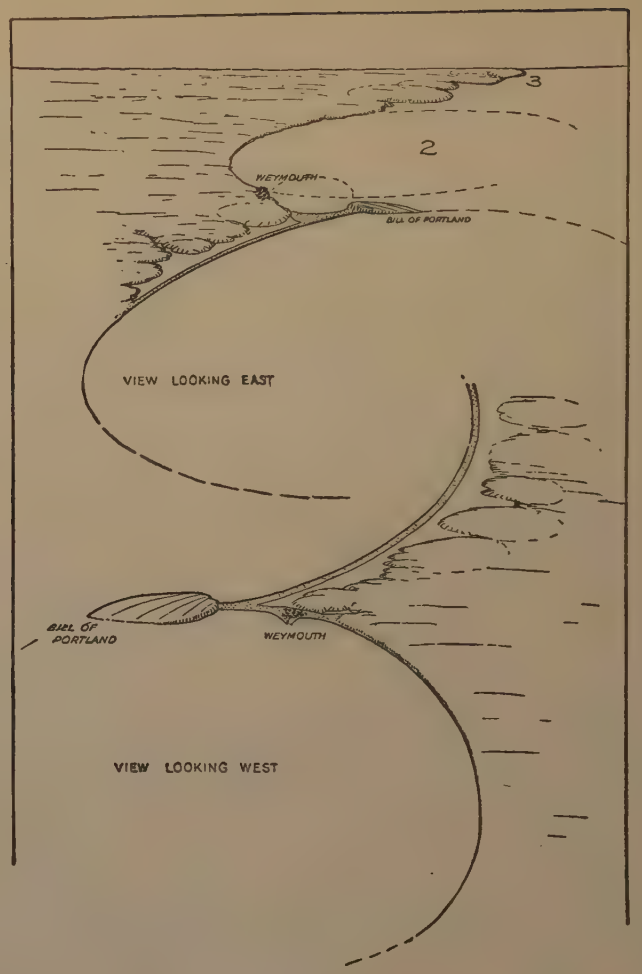


FIG. 174.—Sketches, from different positions, representing the features of the Weymouth sheet, No. 143 (Large Sheet Series), British Ordnance Survey, one-inch map.

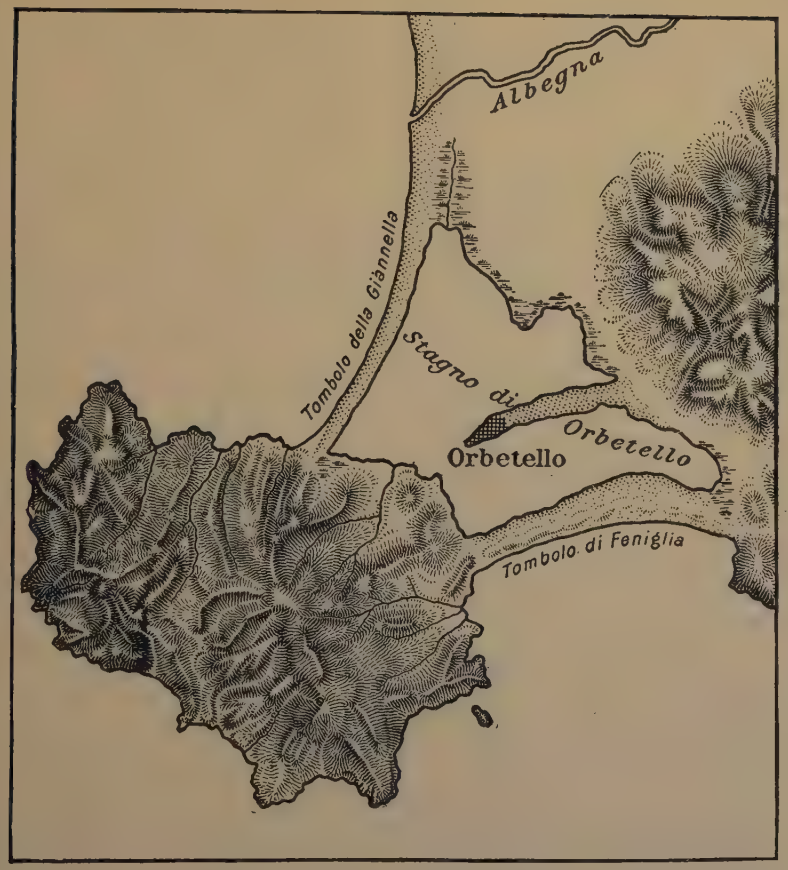


FIG. 175.—Monte Argentario, Italy, tied to the mainland by a double tombolo. A sketch of this, seen from above, is shown in Fig. 176. (From D. W. Johnson, by permission of John Wiley & Sons.)

sketch has a much more natural and pleasing appearance than would be the case if no conscious effort were made to introduce geometrical forms to which perspective methods can be applied.

A detailed map of the Monte Argentario region is shown in Fig. 175. The corresponding sketch (by W. M. Davis),

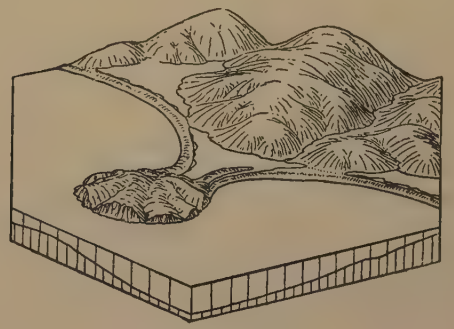


FIG. 176.—Sketch of Monte Argentario, Italy, shown on map in Fig. 175. (From W. M. Davis.)

given in Fig. 176, departs from the map in several details and yet represents the essential features of the region. Note in Fig. 176 that most of the major lines of the drawing can be related to ellipses, much as in Fig. 174.

EXERCISES

Based upon the Illustrations in Chapter XII

Exercise 1. Prepare a series of five drawings, modeled somewhat after Fig. 171, to illustrate the following stages in the development of a shoreline of submergence:

a. Initial stage: no wave work; simply a drowned coast with promontories, islands, and embayments.

b. Early youth: promontories and islands show slight cliffing by the waves.

c. Youth: promontories and islands strongly cliffed; bars and beaches of various kinds. Label on your sketch the following features: cliffed headland, winged headland, spit, recurved spit, compound recurved spit, complex spit, baymouth bar, bayhead bar, midbay bar, bayhead beach, bayside beach, cuspate bar, cuspate foreland, headland beach, looped bar, and tombolo. (Consult Johnson's "Shore Processes and Shoreline Development," if necessary.)

d. Submaturity: promontories considerably cut back and connected by baymouth bars back of which are lagoons; a comparatively straight coast.

e. Maturity: promontories entirely removed, even to the heads of the bays; the coast line is comparatively straight but there are no lagoons, beaches, nor spits.

Exercise 2. Prepare a series of blocks like those in Fig. 173 but turned so that the long lines run off toward the right vanishing point. Also have the nearest block represent the first stage and the farthest block the last stage of the series.

Part II

ISOMETRIC DIAGRAMS AND PROBLEMS IN STRUCTURAL GEOLOGY

110. Isometric projection. Relation between a block and its isometric projection.—Isometric projection or perspective is not a true perspective, but for some purposes it is much more useful. As the term "isometric" connotes, the projection has dimensions along certain directions which are commensurate with each other. All of these dimensions in spite of being taken along different directions, may be made equal to the measurements along the corresponding directions in the actual block which is being put into perspective, or if not equal at least they may all be made on the same proportionate scale of the original. Thus in the isometric projection, Fig. 177, *B*, of a rectangular block, the dimensions along any of the edges are equal to the corresponding dimensions in the block itself. Fig. 177, *A*, represents the several faces of the block in actual size. $a'b'$ in the projection equals ab in the block, $a'e'$ equals ae, $d'c'$ equals dc, $c'g'$ equals cg and $b'f'$ equals bf. For this reason it is very convenient to transform accurately a geological map with definite measurements of faults, strikes, dips, and other data, into a block in which these important relationships are accurately preserved and in which the measurements have similar value in all parts of the drawing along the three co-ordinates.

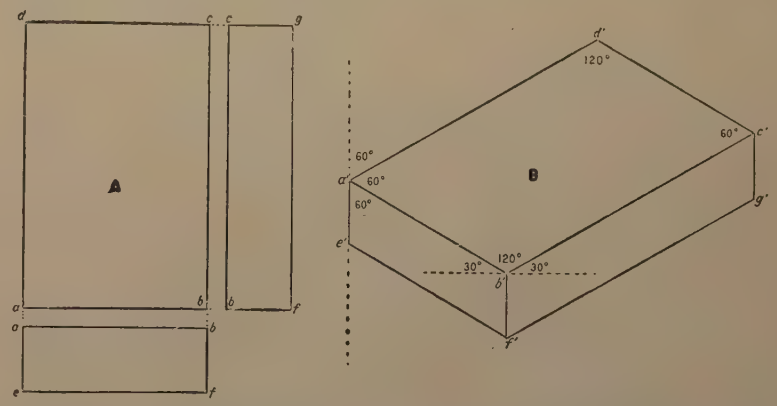


FIG. 177.—Isometric projection. At *A* the true dimensions of the block are shown in plan, and front and side elevations. At *B* the isometric projection is drawn out on the same scale. That is, $a'b'$ equals ab; $b'c'$ equals bc; $c'd'$ equals cd, etc. The angles at the corners, 60 degrees and 120 degrees, are arbitrarily chosen because of the convenience in drawing these with the usual 30–60-degree triangle. Other angles are equally satisfactory. In the isometric block parallel lines are drawn parallel and all measurements along the three main co-ordinates are comparable and can be transferred directly from the original plan or elevations, shown in *A*.

To transform a block such as that shown in *A*, Fig. 177, into an isometric projection, draw a lozenge-shaped figure $a'b'c'd'$ with the opposite sides parallel and allow $a'b'$, $b'c'$, $c'd'$, and $d'a'$ to equal respectively *ab*, *bc*, *cd*, and *da* in the block. Then from each corner drop vertical lines $a'e'$, $b'f'$, and $c'g'$ equal to *ae*, *bf* and *cg*. Connect $e'f'$ and $f'g'$. The angles which the sides of the projected block make with each other and with the horizontal need not for our purposes necessarily conform to any requirement. Usually the sides are drawn at angles of 60 degrees and 120 degrees with each other and in the position indicated in Fig. 177, *B*, because standard isometric cross-section paper is supplied in this pattern and also because the blocks are more readily constructed with the 30-60-degree triangle. The several blocks shown in Fig. 178 illustrate the use of various angles. Although these three blocks (Fig. 178, *A*, *B*, *C*) differ in appearance, nevertheless their corresponding dimensions along the three co-ordinates are equal to the dimensions of the block in Fig. 177, *A*, which they represent. Consequently these projections lend themselves readily to the accurate representation of geologic facts.

111. General rules of isometric perspective.—It will be realized now that in isometric drawings the following rules always apply:

1. Measurements may be made to scale anywhere upon the upper surface of the block in the direction of either of the two co-ordinates, which in the object itself are at right angles to each other.

2. Distances in other directions are not commensurate with each other unless measured along lines parallel to each other, and they are not commensurate with distances measured on the sides of the block.

3. All lines parallel in the object itself are parallel in the isometric drawing.

4. All lines vertical in the object are vertical in the drawing.

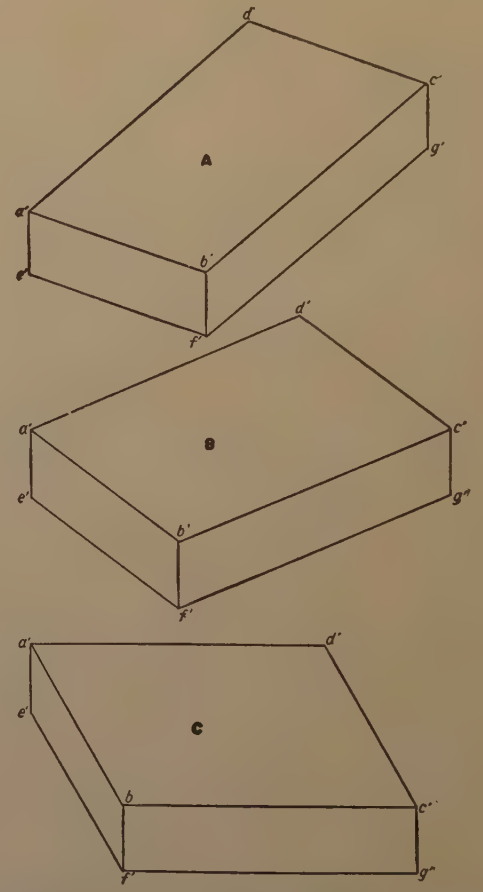


FIG. 178.—Several positions, in isometric perspective, of a block having dimensions of *A* in Fig. 177.

5. If the vertical scale of the drawing is the same as its horizontal scale, then the measurements made in the direction of any of the three co-ordinates are commensurate.

6. All angles in an isometric drawing are distorted, and even two angles lying in the same plane can not be compared with each other unless they lie in exactly similar positions.

112. Application of isometric projection to presentation of geological facts. From data supplied by three vertical drill holes to show dip and strike of the formation.—At the outset it should be stated that from the point of view of this book this is a problem in draftsmanship and not one in geology. The endeavor here is simply to show how this can be drawn so that the various facts can be laid out before a reader. The slightly different method used in Section 113 will enable one to determine graphically the actual strike and dip in degrees.

Figure 179 represents a map showing the location of three drill holes. Their co-ordinates, a_1 a_2, b_1 b_2, c_1 c_2, represent their distances from the sides and ends of the map. The top of hole A is 230 feet above sea, and at a depth of 330 feet the boring pierces formation x in question. Similarly, the top of hole B is 130 feet above sea, and at a depth of 310 feet enters formation x. Hole C has its upper end at 80 feet above sea, and has a depth of 390 feet before it enters formation x. The representation of these facts and the solution of the problem may be accomplished in the following manner:

Draw an isometric block of the area shown in Fig. 179 and indicate on its surface the location of the drill holes as in Fig. 180. The surface of the block may represent sea level. The horizontal scale of the block is the same as the scale of the map which it represents. The location of the points A, B, and C is determined by measuring their co-ordinates parallel respectively to ef and fp. so that a_1 equals

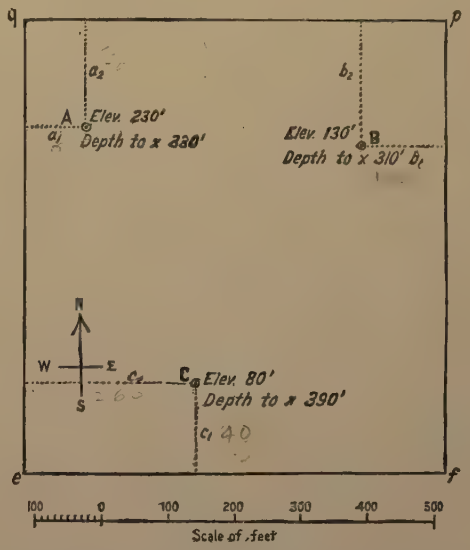


FIG. 179.—Map of area with location of three drill holes, A, B, and C. The elevation of the holes above sea level is given and also the depth of each hole to formation x. In the following figures this map is transformed into an isometric block with these facts graphically expressed.

a_1', a_2 equals a_2', b_1 equals b_1', b_2 equals b_2', c_1 equals c_1', c_2 equals c_2'. The next step is shown in Fig. 181. This represents the drill holes as vertical lines. A convenient vertical scale, which may or may not be the same as the horizontal scale, is selected. At 230 feet above A', the point A'' represents the top of the first drill hole. At 330 feet below

A'', that is, 100 feet below sea level, the point a represents the point where the boring pierces formation x, the top of the block being taken at sea level. Similarly, the vertical lines $B''b$ and $C''c$ represent the second and third drill holes drawn to scale.

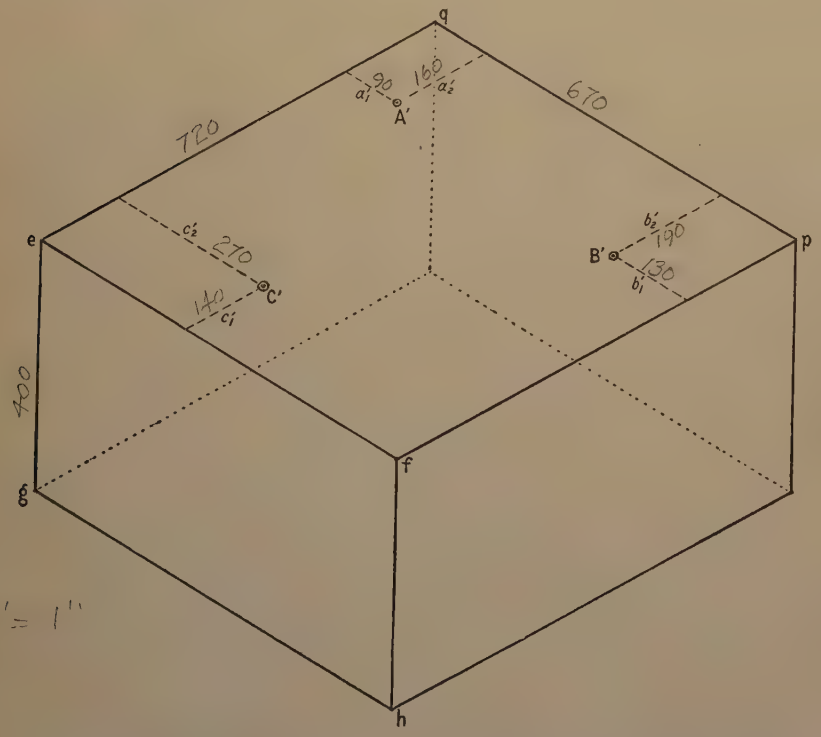


FIG. 180.—Isometric projection of Fig. 179 with location of the three drill holes. The position of the holes is readily determined by measuring their distances from the sides of the block.

The points a, b, and c may now be connected as in Fig. 182 and the area thus included may be shaded to simulate a plane surface. The next problem is to represent the strike and dip of this formation. Consult Fig. 183. The direction of strike may be represented by indicating the intersection of the plane of the formation (abc) with the top of the block.

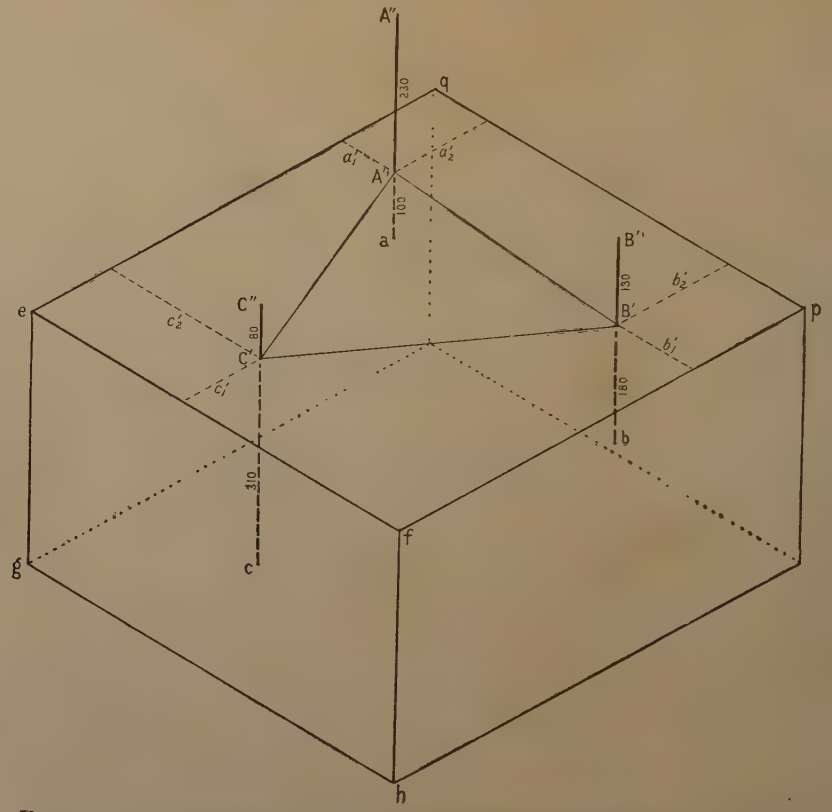


FIG. 181.—Same as Fig. 180 with the vertical drill holes represented by heavy vertical lines drawn to scale. The points A'', B'', and C'' represent the tops of the holes at the surface of the ground. The points a, b, and c represent the points where the holes pierce a given geological formation x.

Thus, by extending *ba* upward until it intersects the continuation of $B'A'$ on the surface of the block at *l*, one point where the plane *abc* cuts the surface of the block is determined. Similarly, by extending *ca* upward until it intersects the continuation of $C'A'$ at *m*, another point is determined, thus giving the intersection of these two planes $A'B'C'$ and *abc*. This gives the strike and represents the outcrop of this formation on a plane at sea level. If the line *cb* is also extended upward until it intersects $C'B'$ extended, at the point *n*, it will be noted that the three points *lmn* form a straight line because they all lie in the plane of the formation in question as well as in the plane representing the top of the block. The line *lmn*, therefore, shows graphically the direction of strike. It shows also that the formation does not outcrop within the limits of the map.

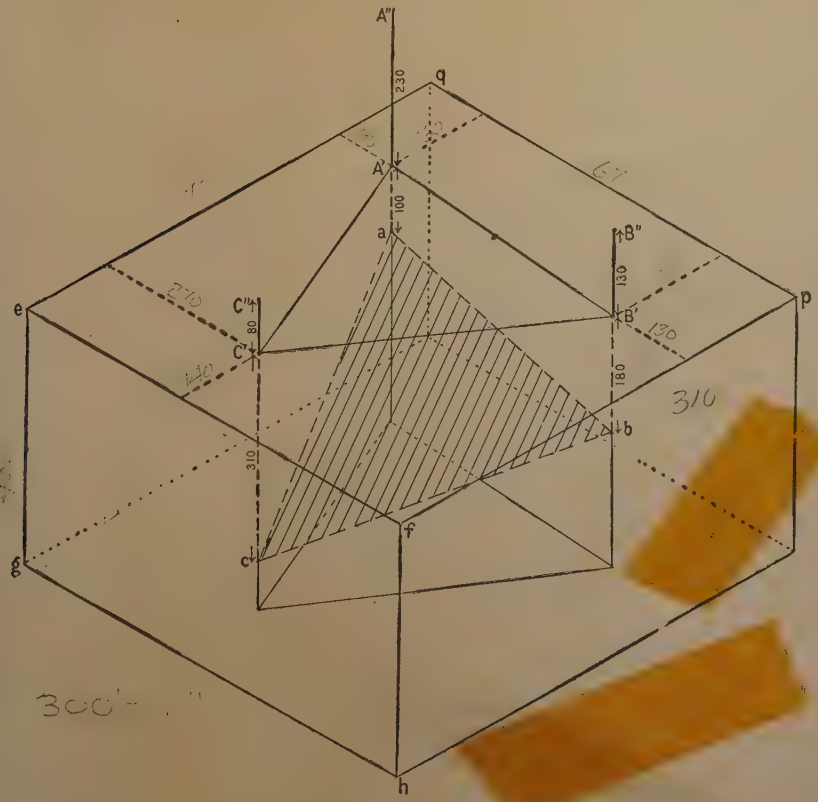
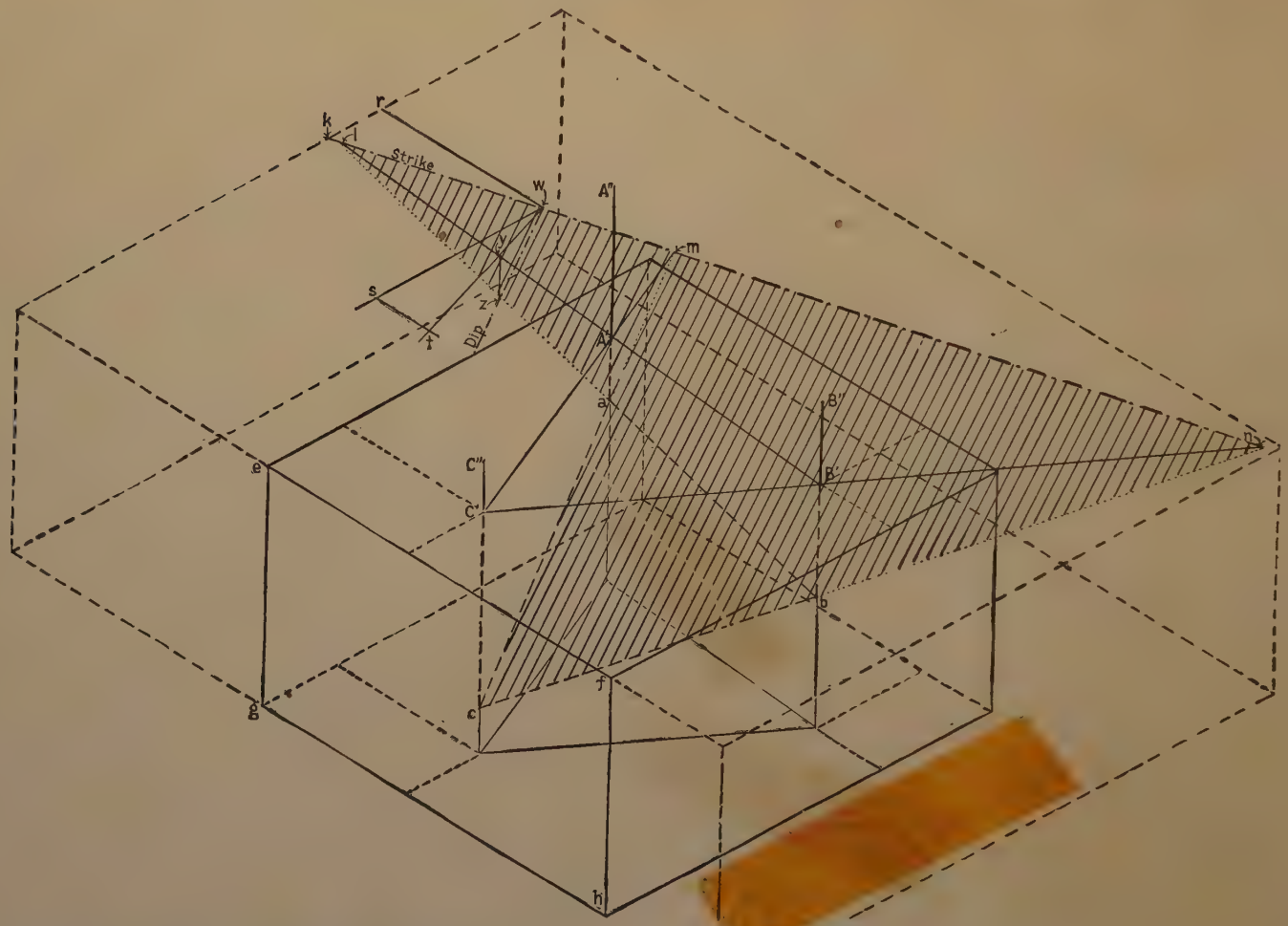


FIG. 182.—Same as Fig. 181. The points *a*, *b*, and *c* are connected and the area thus outlined is shaded to simulate the plane of formation *x*.

To indicate the dip of the shaded plane representing the formation, it is necessary to draw a line down its slope at right angles to the strike. This will, of course, not be at right angles in the perspective drawing. In order to determine the direction of *wt*, which represents a line at right angles to *lmn* on the surface of the block, proceed as follows: Construct the perspective view of the two equal right-angled triangles *krw* and *tsw* on the top of the block so that *rw* equals *sw* and *kr* equals *ts*. The line *sw* is parallel to *kr*. The angle *swt* then represents the equal of *rwk*. Since *swr* represents a right angle, *twk* also does. The line *tw* then represents the direction of dip but on a horizontal plane. At *y*, where *wt* cuts $A'l$, drop a vertical line until it cuts *al* at *z*. The plane *ywz* then represents a vertical plane normal to the direction of strike. Consequently, *wz* indicates the direction of dip. It will be noted that the ruled shading on the plane of the formation has purposely been made to conform to the dip.

113. Graphic solution of problem presented in Section 112.—In addition to the presentation of geological facts, as in the case just considered, the isometric drawing lends itself to the actual solution of problems even where the question of presentation does not enter.



300' = 1"

FIG. 183.—An extension of Fig. 182. The plane *abc* has been extended so as to intersect the top of the block (sea level) in the line *kmn*, which therefore represents the strike of the formation. See Section 112 of the text for complete explanation.

It is obvious that from Fig. 183 it is impossible to read off the true strike or the dip in degrees, although the drawing

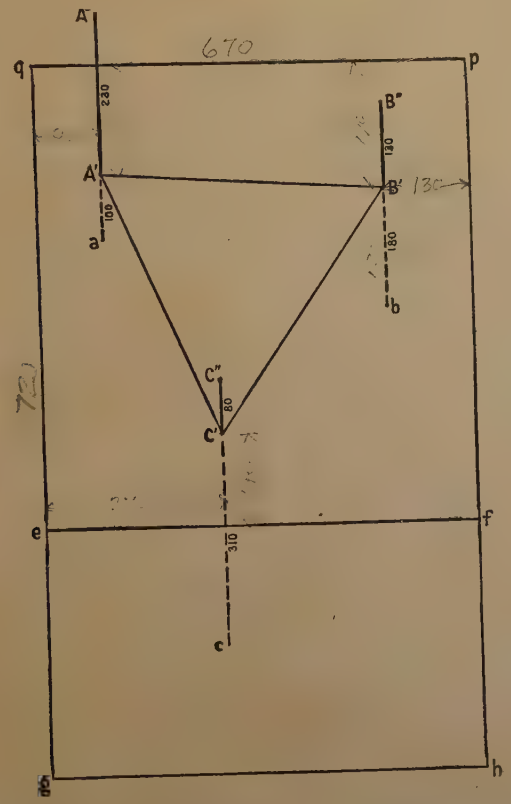


Fig. 184.—Modified form of isometric block. This figure corresponds with Fig. 181. The points *pqef* outline the top of the block. The points *efgh* outline the front of the block. The sides are not visible. The drill holes are represented to scale as before.

enables one to visualize the situation. A slight modification of the isometric drawing, however, enables one to follow the same methods and attain a solution which is more useful in that it gives distances and directions which are not distorted by projection. Fig. 184 corresponds to Fig. 181.

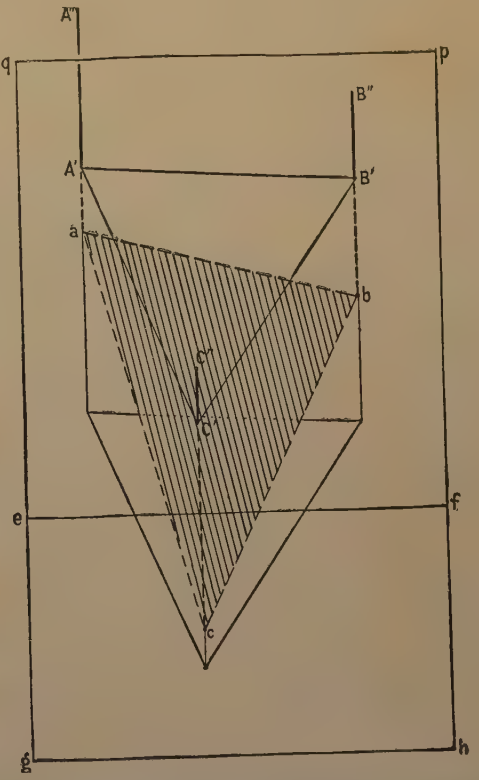


Fig. 185.—Same as Fig. 184 with plane of formation x represented by shaded surface. This figure corresponds with Fig. 182.

The top of the block has not been distorted, but is left the same shape as the map. The front of the block is also shown in its true form. A block of this character, Fig. 184, does not

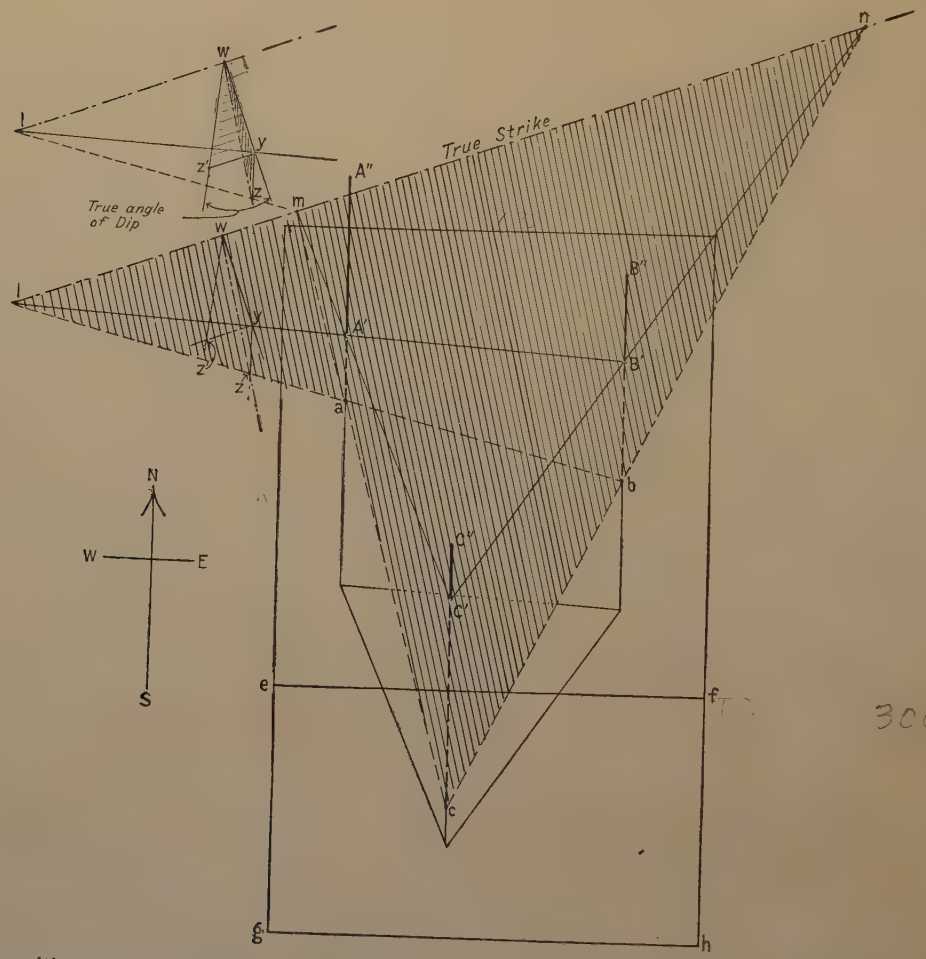


FIG. 186.—Same as Fig. 185 with position of strike indicated. This figure corresponds with Fig. 183. In this case *lmn* represents the true direction of strike, if the map is oriented on the paper in the usual way. It is therefore more useful than Fig. 183. The inset shows how the vertical angle *ywz* is swung around into the horizontal plane so that the dip may be read.

resemble a block at all and for that reason lends itself less readily to the teacher or draftsman as a tool for presenting facts. But it has certain useful qualities, as follows:

1. All measurements upon the surface of the block in all directions may be made to scale, and all angles lying in the plane of this surface or any plane parallel thereto, regardless of their positions, are true, because the surface of the block is nothing more nor less than the map itself.

2. All vertical lines in the object are vertical in the drawing and are true to scale.

3. As in isometric projection, all lines parallel in the object are parallel in the drawing, regardless of position.

Figure 185 corresponds to Fig. 182 and shows the plane of the formation *abc*. Fig. 186 corresponds to Fig. 183 and shows the points *l*, *m*, and *n* determined by the intersection of the plane *abc* with the plane *A′B′C′*. But since the line *lmn* lies on the surface of the block, it has its true direction and represents the true strike. It represents the outcrop of the formation in a plane at sea level.

To find the true angle of dip, draw *wy* perpendicular to *lmn* at any point *w*. Where *wy* intersects *B′A′l* (it may intersect *C′B′n* or *C′A′m*, in which case proceed similarly) at some point *y* drop a vertical line until it intersects *bal*, that is, until it pierces the plane of the formation at some point *z*. The vertical angle *ywz* is the angle of dip. This angle may be swung around into the plane of the drawing by drawing *z′y* equal to *zy* and perpendicular to *wy*. The angle *ywz′* then equals the true angle of dip.

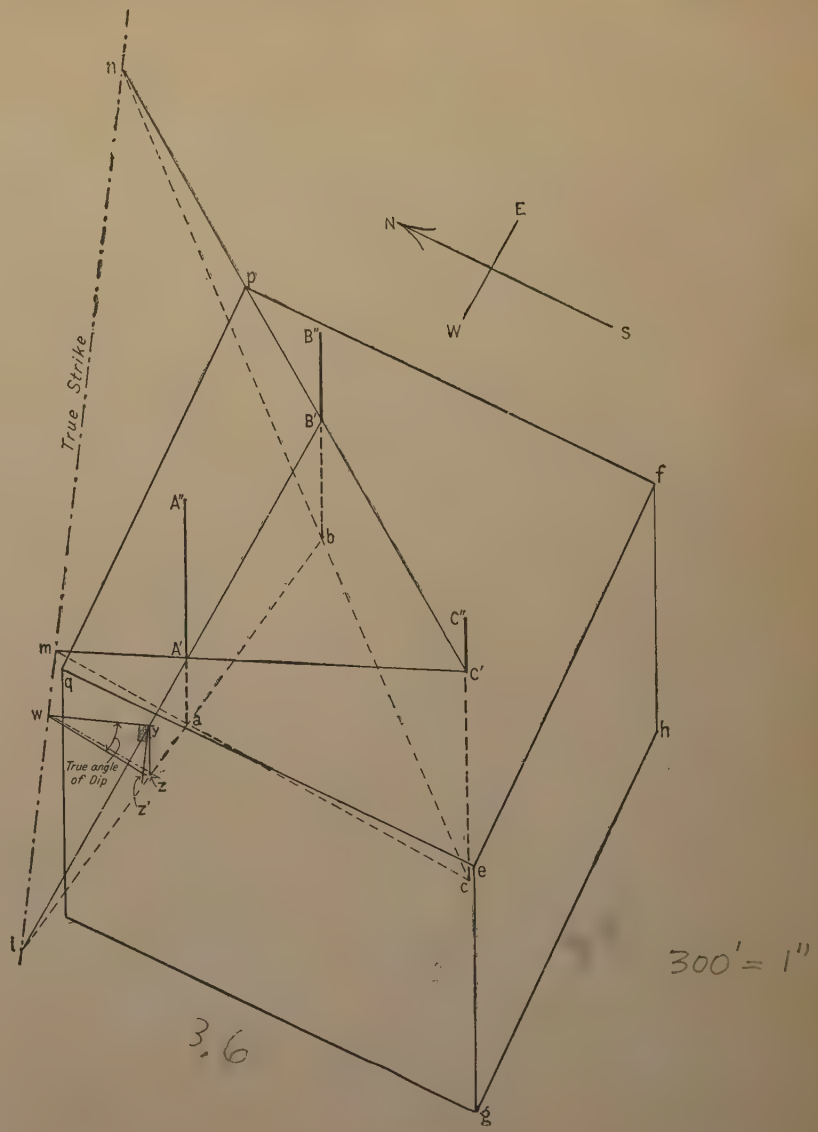


FIG. 187.—A special form of isometric block. Similar to Fig. 186 in that the top of the block is not distorted. The top of the block is at a slight angle with the vertical so that an aspect of solidity is given to the block, a feature which is lacking in Fig. 186.

In the event that two of the drill holes are almost on a north-south line, the map may be turned so that the lines connecting them make as large angles as possible with the vertical. Thus in Fig. 187 the whole map has been turned with the development of an entirely new set of construction lines, but the result obtained is the same as in Fig. 186. From this it is evident that by turning the map at an angle to the vertical a form of isometric block may be produced whose surface is exactly the same as the map itself. For many purposes, then, it may be observed that a block of this kind, like Fig. 187, is more useful than any other form of drawing for the solution of certain problems in structural geology. It enables one not only to visualize the essential facts of the situation, but actually to solve graphically the

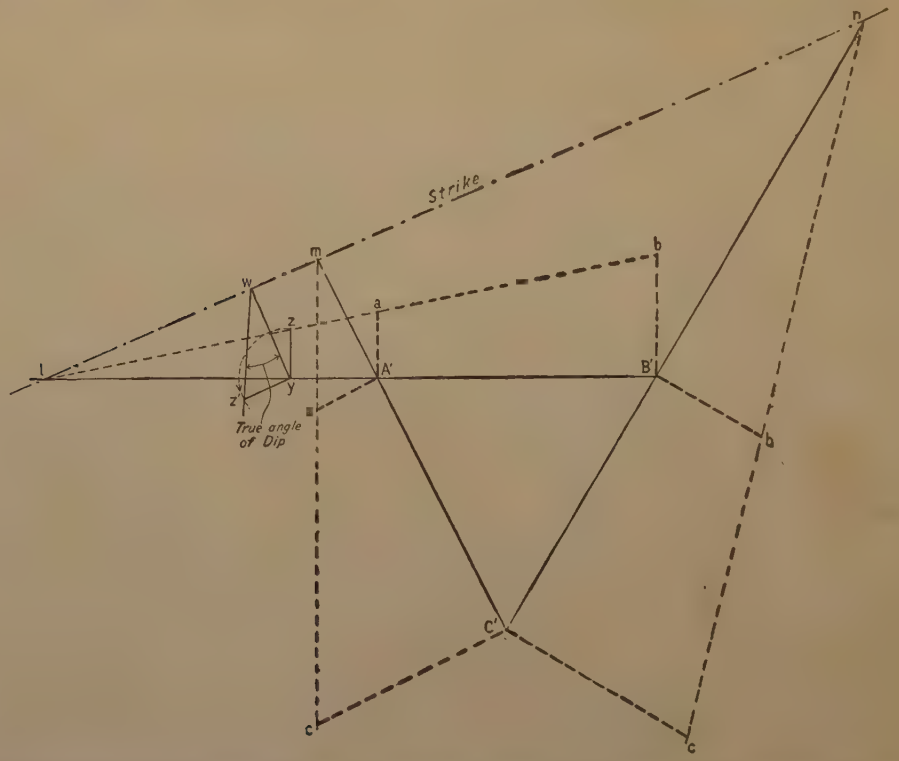


Fig. 188.—Graphic solution without the use of isometric block, of problem discussed in Section 113 of the text. See Section 114 for explanation. Same scale as Figs. 179 to 187.

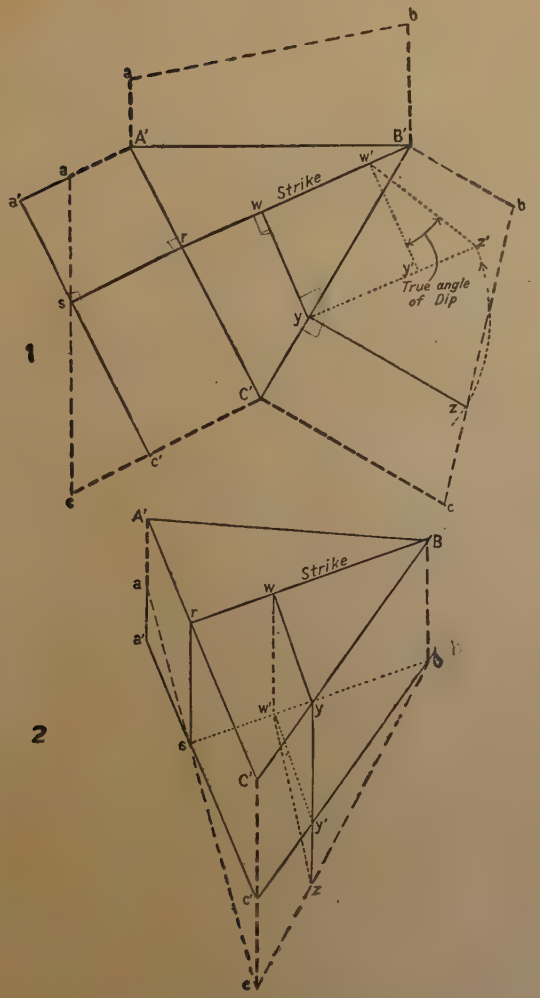


FIG. 189.—Determination of strike and dip from data supplied for Fig. 188 (distances, depths, and scale as given in Fig. 179). The construction here, however, permits a solution within a much smaller area and does not involve a determination of actual outcrop, or outcrop on sea-level plane as in Fig. 188. (See Section 114 of text for explanation). Block 2 is simply a perspective view of the construction lines and is not necessary in solving the problem.

problem in hand. Even when more accurate solutions are desired than are possible by graphic means, the usual formulae may be used, but a graphic drawing is always desirable in aiding the investigator to form clearly in his own mind a picture of the situation and thus to guard against reaching a result which may be quantitatively exact but diametrically wrong as to direction.

114. Graphic solution of problem without use of isometric block.—Still another device may be followed in solving the problem under consideration. Thus in Fig. 188 all the vertical planes, such as $A'aC'c$, $B'bA'a$, $B'bC'c$, have been swung into the horizontal. The resulting construction lines may therefore be drawn more accurately than when the angles between them are distorted. The line lmn indicating the strike is determined by extending the lines cb, ca, and ba until they intersect respectively $C'B'$, $C'A'$, and $B'A'$, each extended. The true angle of dip is determined by drawing wy perpendicular to lmn at any point w. The line yz is then drawn perpendicular to lB', and $z'y$ is then drawn perpendicular to wy and equal to zy. The angle ywz' then equals the true angle of dip.

When the line lmn is far away from the drill holes A', B', and C', as in the case of a formation with gentle dip, or if the drill holes go very deep before piercing the formation, then the method for obtaining strike shown in Fig. 189, 1, is advantageous. The line $a'c'$ is drawn parallel to $A'C'$ at a distance $B'b$ from it. The distance $B'b$ represents the one of the three holes which is of intermediate depth. This gives some point s in the plane of the formation ca which is

at the same depth as the point b. The line bs (shown in perspective in the lower figure) is a horizontal line and represents the strike. In the map view (Fig. 189, 1) the line $B'r$ corresponds to bs, the point r being determined by erecting a perpendicular to $A'C'$ from the point s. The true dip is determined by drawing wy perpendicular to $B'r$ at any point w until it intersects $B'C'$ at y. Then drop yz perpendicular

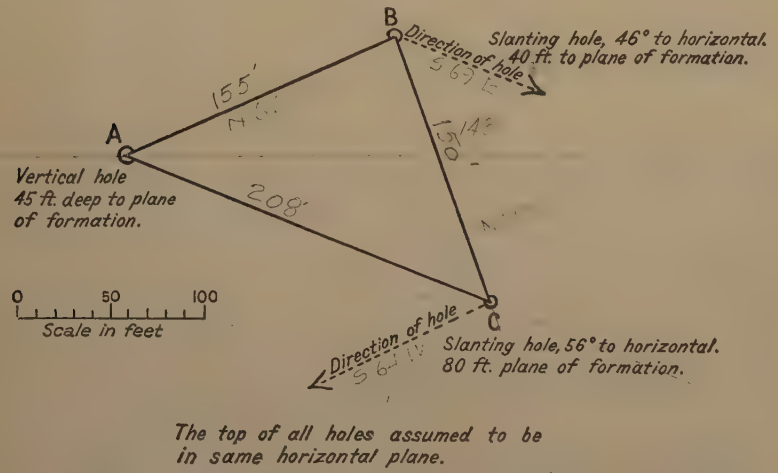


Fig. 190.—Data involving three drill holes, two of them slanting. The determination of strike of the formation is given in Fig. 192.

to $B'C'$ until it intersects bc at z. Then draw yz' equal to yz and perpendicular to wy. Then draw $w'y'$ equal to wy and at a distance therefrom equal to $B'b$. The angle $z'w'y'$ equals the true dip. Comparison of the map view, Fig. 189, 1, with the isometric perspective view, Fig. 189, 2, will help to visualize the operation. In ordinary work, however, the upper drawing alone would suffice.

115. Graphic solution of problem. Given three drill holes, one or more being oblique to the horizontal, all piercing a known formation at known depths, to determine strike and dip of the formation.—Figure 190 presents the known facts of the problem. A is the vertical hole, which goes down 45 feet before reaching the formation in question. B is a slanting hole. Its slope is 46 degrees to the horizontal, along a somewhat southeasterly line, the direction of which is

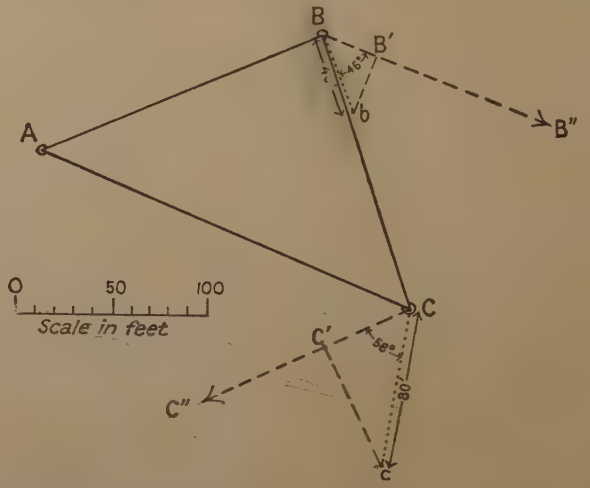


Fig. 191.—Determination of points B' and C' from data given in Fig. 190. B' is vertically above the point b where the hole B pierces the formation. C' is vertically above the point c where the hole C pierces the formation.

precisely shown on the map (Fig. 190). C is a second slanting hole. Its slope is 56 degrees to the horizontal along a somewhat southwesterly line, the direction of which is precisely shown on the map. The tops of all the holes are assumed to be in the same horizontal plane. It is necessary first to find, for the slanting holes B and C, points on the ground which are directly above those places where the

borings pierce the formation, and second, to know the vertical depth below those points to the formation. This is done graphically in Fig. 191 by drawing to scale Bb, 40 feet long at an angle of 46 degrees to BB', and by drawing Cc, 80 feet long at an angle of 56 degrees to CC'. From b and c erect perpendiculars to BB'' and CC'' to locate B' and C'. Using B' with a depth of $B'b$ and C' with a depth of $C'c$, follow the procedure indicated in Fig. 192, which is exactly the same as the procedure in Fig. 188. The drawing in Fig. 192 shows only the determination of the strike. The dip may be determined as in Fig. 188.

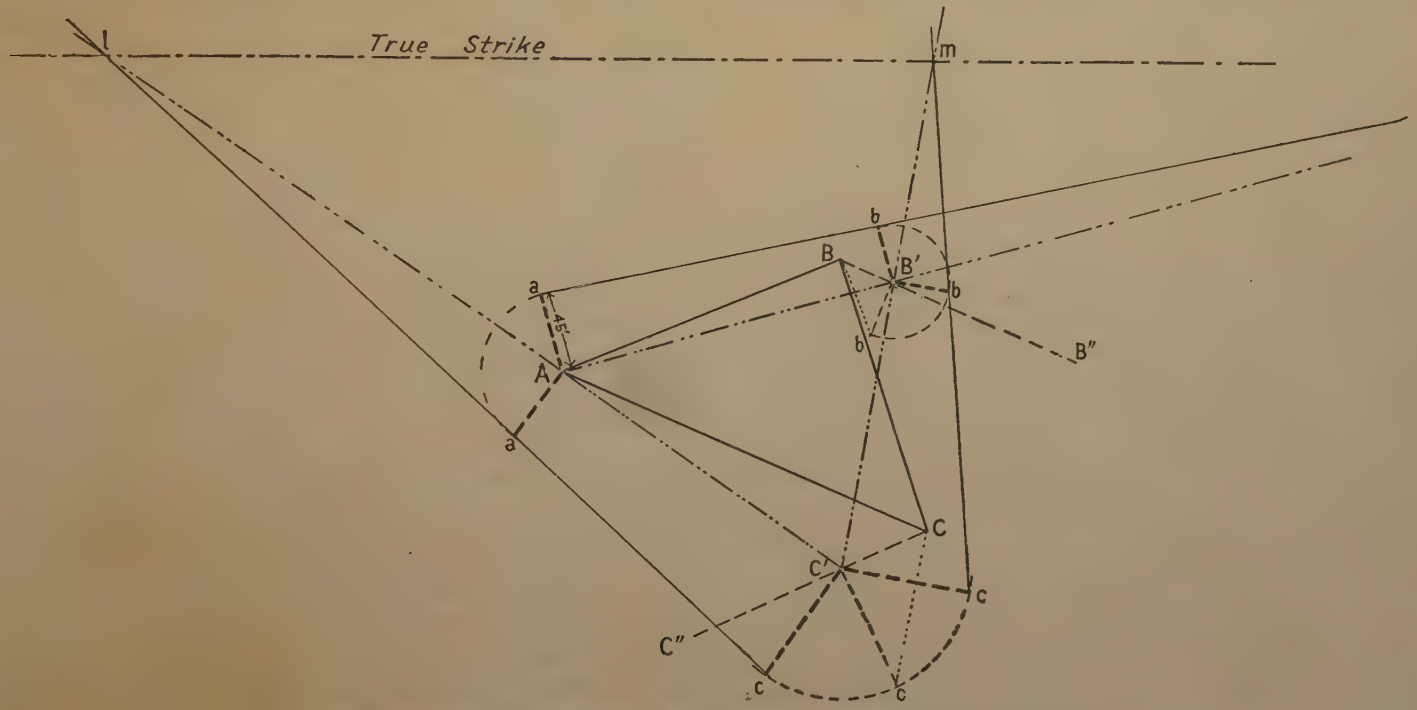


FIG. 192.—Solution of problem for which data are given in Figs. 190 and 191.

116. Graphic solution of problem. Given two drill holes, one vertical, the other slanting. In each case the angle the core makes with the bedding plane is known. To determine true strike and dip.—The known facts of the problem are shown in Fig. 193, 1. V represents the position of a vertical drill hole which cuts the bedding planes through which it passes at an angle of 40 degrees. S represents the

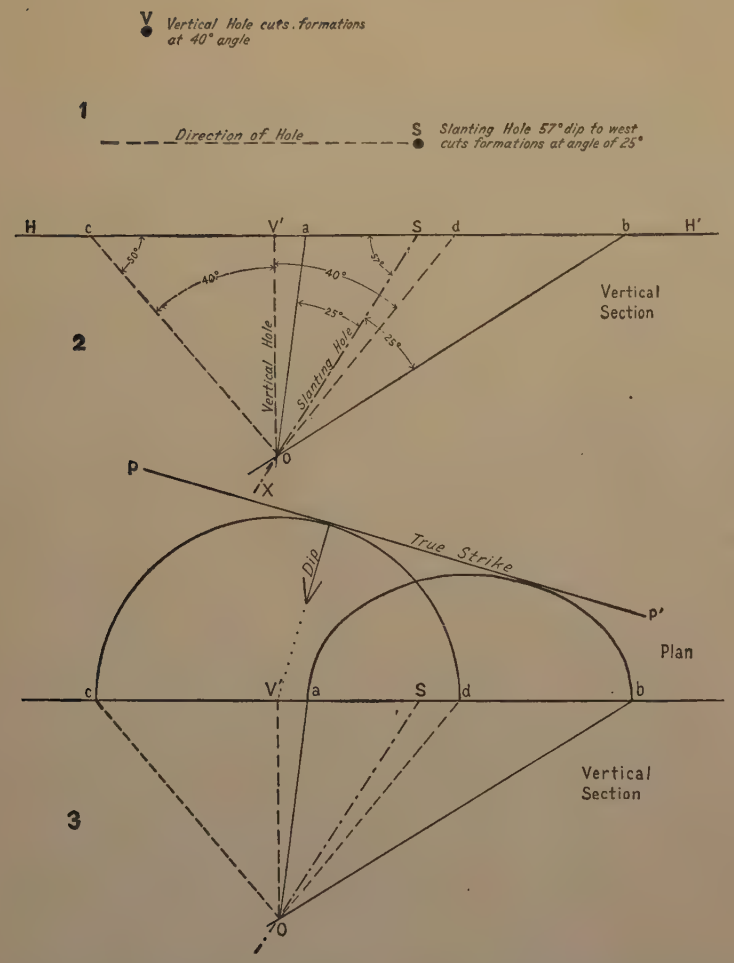


FIG. 193.—Determination of direction of strike when angles between bedding plane and vertical hole, and between bedding plane and slanting hole are known. (See Section 116 of text for explanation.)

position of a slanting hole dipping westward at 57 degrees and cutting the formations through which it passes at an angle of 25 degrees. No particular formation is assumed to be identifiable in the two holes. The problem is to determine the dip and strike of the stratified series. The dip obviously is 50 degrees. As the beds make an angle of 40 degrees with the vertical they must make an angle of 50 degrees with the horizontal.

Now, to determine the strike proceed as follows: Put a vertical plane through the slanting hole S as in Fig. 193, 2. SX represents the slanting hole and makes an angle of 57 degrees with the horizontal. The bedding planes form an angle of 25 degrees with the slanting hole. Therefore, the locus of all planes satisfying this requirement is determined by the surface of a cone whose axis is the slanting hole and whose apical angle is 50 degrees (25 degrees plus 25 degrees equals 50 degrees). Therefore, through any point O, on the slanting hole, draw Oa at 25 degrees to OS and Ob at 25 degrees to OS; aOb then represents the section of the cone. This slanting cone is cut by the horizontal plane HH' representing the surface of the ground in the ellipse ab shown in Fig. 193, 3. The drawing of this ellipse is explained in the next section, 117, of the text. Any plane tangent to this cone conforms with the requirements of the case in being cut by the slanting hole at an angle of 25 degrees.

Proceed next with the vertical hole. This hole cuts the bedding planes at 40 degrees. It is obvious that the exact location of this hole does not enter into the problem because any vertical hole would cut the bedding planes at the same angle. Therefore imagine a vertical hole passing through the point O. About this hole as an axis rotate the line Oc at an angle of 40 degrees thereto, so as to develop a cone

cOd. Any plane tangent to this cone satisfies the requirement in being cut at an angle of 40 degrees by the vertical hole. Therefore, any plane passing through *O*, and tangent to both ellipse and circle meets all requirements and its trace upon the ground gives the true strike, *PP'*, Fig. 193, 3. Any plane passing through *PP'* and *O* is tangent to both cones, is cut by any slanting hole similar to *S* at an angle of 25 degrees and by any vertical hole at an angle of 40 degrees. In particular, the line *PP'* represents the outcrop of a bed cut by a vertical and slanting hole at the point *O*. If *O* had been selected at a greater depth the line *PP'* would have been farther away but parallel to *PP'*. The depth of *O* does not affect the strike. The direction of dip is at right angles to the strike toward the center of the circle.

Reference to Fig. 194 will now show that the line *PP'* does not exhaust the possibilities, for another line P_1P_1' may also be drawn tangent to both circle and ellipse. The dip in this case would be northerly. Thus, this problem is indeterminate. Two solutions are possible.

Reference to Fig. 199, p. 137, will show that this problem has many possibilities depending upon the relative size and position of the circle and ellipse. For instance, in Fig. 199, 1, there are two directions of strike which will meet the requirements as both *AB* and *CD* may be drawn tangent to both the circle and the ellipse. Fig. 199, *X* gives a perspective view of the two cones developed around the two drill holes, one vertical, the other slanting. In this case the two cones intersect each other as they do in Fig. 194. Fig. 199, 2, gives a similar case, but the minor axis of the ellipse is equal to the diameter of the circle and the direction of the strike is definitely determined, but the dip may be in either direction.

Figure 199, 3 and 4, show conditions similar to those in 1 and 2 but the two cones do not intersect each other; consequently there are four solutions to the problem. Block *Y* shows the relation of the cones to each other. In Fig. 199, *Z*, the cones are tangent, giving therefore three solutions as shown in 5. *AB* and *CD* may or may not be

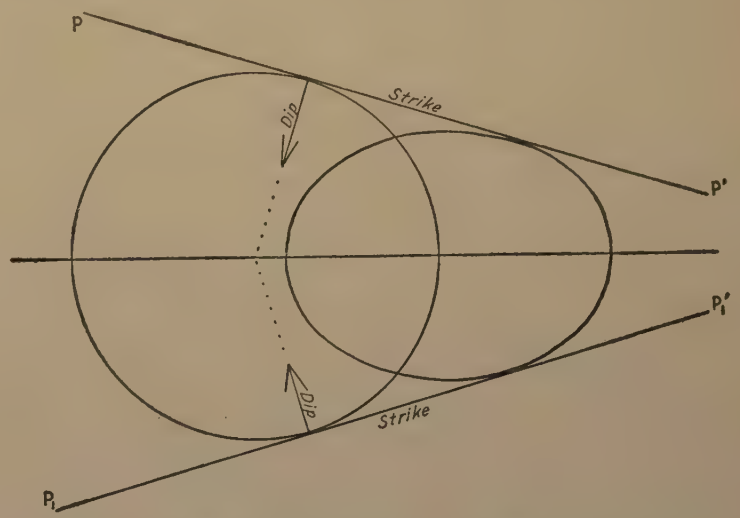


FIG. 194.—Complete solution of Fig. 193, 3. Two possible directions of strike are obtained and the problem is, to this extent, indeterminate.

parallel, depending on the size of the ellipse. In Fig. 199, 6, the two cones are tangent, but the vertical cone is included within the slanting cone so that *EF* is the only line that may be drawn tangent to both circle and ellipse and the problem is therefore determinate. This would rarely occur. Fig. 199, 9, illustrates the same condition when the slanting cone is included within the vertical one. In Fig. 199, 7, the ellipse is so reduced in size as to become only a point and

one solution results. This is the case when the slanting hole happens to follow down the dip of the beds. If the slanting hole happened to follow one of the bedding planes without going directly down the dip, the ellipse would be reduced to a point, but it would be distant from the circle and two solutions for strike would result. In Fig. 199, 8, the circle has been reduced to a point upon the circumference of the ellipse. One solution is therefore possible. This condition results when the beds have a vertical dip and the strike is normal to the major axis of the ellipse. But if the point representing the circle is distant from the ellipse, two solutions are possible. Such a condition results when the dip is vertical but when the strike is not normal to the major axis of the ellipse.

A full discussion of the various possibilities of this problem is given by W. J. Mead: Determination of Attitude of Concealed Bedded Formations by Diamond Drilling. Economic Geology, Vol. XVI, pp. 37 to 47, 1921.

117. Construction of the ellipse formed by a plane cutting a cone at a given angle. (*This explains the construction of the ellipse in Fig. 193 and Fig. 194, Section 116, the same data being used.*)—In Fig. 195 a perspective view shows the cone $ADCX$ cut by a horizontal plane in the ellipse LRN. The construction of the actual ellipse LRN is shown in Fig. 196. The line BX represents the axis of the cone. AX and CX, the sides of the cone, make equal angles with BX. Draw AC at right angles to BX at B and construct the circle ADC (Fig. 196). This represents a section of a cone perpendicular to its axis. Imagine next any plane such as BEX, Fig. 195, put through the axis of the cone. Thus in the construction (Fig. 196), draw any line, BE, a radius of the circle. Draw EE' perpendicular to AC to determine the point E'. E' is the projection on the vertical plane of the drawing, that is upon the vertical section of the cone ACX, of the point E which is on the rim of the cone. Draw XE' to represent the projection of XE, as shown in Fig. 195, upon the plane ACX. XE cuts the horizontal plane of the ellipse in the point R, Fig. 195. The problem is to determine the position of point R. This is done by determining the length of KR. K is the projection of the point R upon the plane of the drawing and is determined by the intersection of XE' with LN. In other words, it is the problem of determining the intersection of one of the elements of the cone (XE) with the horizontal cutting plane LRN. Conceive next a little plane $FGRK$ perpendicular to ACX and intersecting the plane of the ellipse in KR, K being the projection of the point R upon the plane ACX. This is done in order to project the points R and K upon the plane of the circle. Thus F is the projection of the point K and is drawn by drawing KF perpendicular to AC (Fig. 196). G is determined by drawing FG perpendicular to BC to intersect BE in G. The distance KR which equals FG may readily be constructed by erecting a perpendicular at K with a length FG. The point R gives one point on the ellipse. The construction shown in Fig. 196 is the one usual in descriptive geometry. Fig. 195 is introduced simply to help visualize the situation.

The most practical method of drawing the ellipse LRN is to select the point K in the middle of LN and thus obtain the length of the minor axis. The line KR then is half the minor axis of the ellipse, and the ellipse may be constructed by the trammel method. To do this:

1. Take any card or straight edge (Fig. 197) and lay

off *J1* and *J2* equal respectively to the semi-major and semi-minor axes.

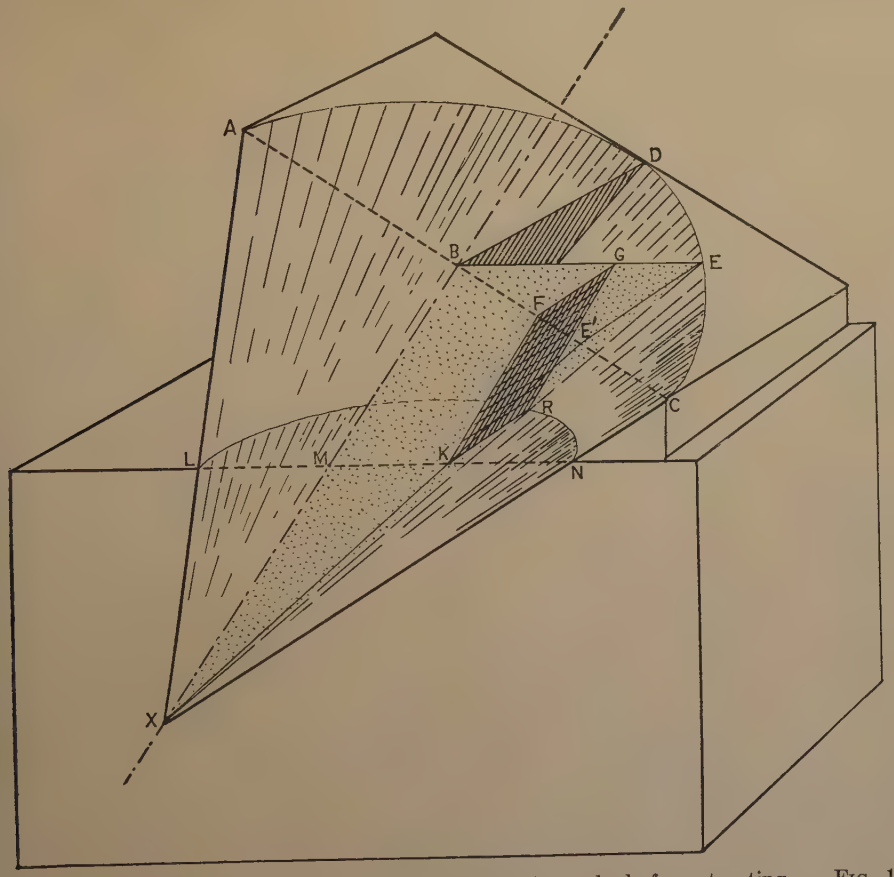


FIG. 195.—A perspective drawing designed to explain method of constructing ellipse formed by intersection of a plane not normal to the axis of a cone.

2. Place the straight edge so that 2 lies on the major axis and 1 lies on the minor axis, and mark the point *J*. (Fig. 197).

3. Do this in as many positions as desired, marking a number of points on the curve.

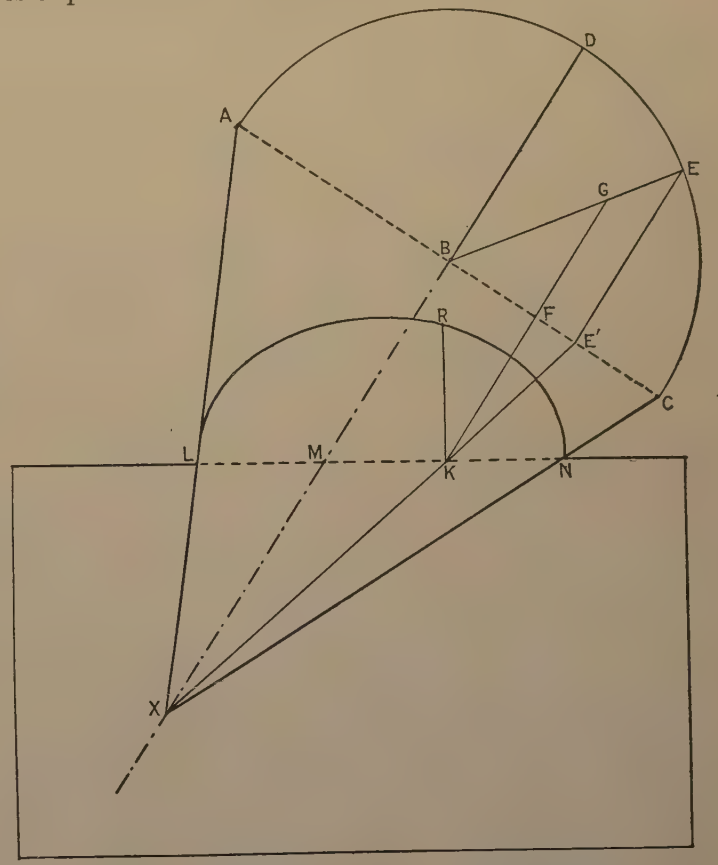


FIG. 196.—Construction of ellipse *LRN* formed by plane cutting cone *AXC* at an angle. See Section 117 of text for explanation.

4. Draw a smooth curve through the points thus obtained.

118. Graphic solution of problem. Given location and depth of vertical hole to a certain formation *x*, and inclina-

tion of bedding plane to hole; given location of slanting hole, and direction of hole and inclination of beds to the hole; flat topography. To determine outcrop of formation *x*, its dip and strike.—Figure 198, 1, represents the known facts and shows in plan the position of the two holes.

Figure 198, 2, represents the graphic solution of the problem. In the solution of the problem the position of V is

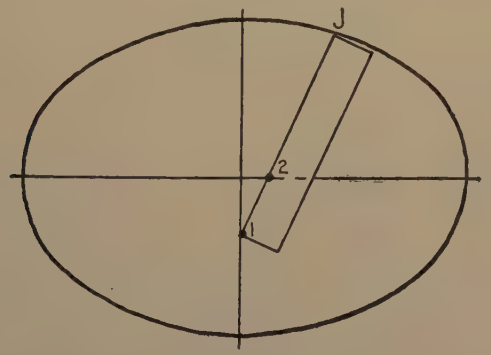


FIG. 197.—Trammel method of drawing ellipse. See Section 117 of text for explanation.

maintained, but it is obvious that the position of S may be altered without modifying in any way its inclination to the bedding. Therefore at V drop the vertical line VX to scale 125 feet. Select some point S' east of V so that $S'X$ makes an angle of 48 degrees with the horizontal. These lines VX and $S'X$ represent the vertical and slanting holes. At X they pierce the formation.

Construct the angle VXL at 35 degrees. LX then represents the dip of the formation x, 55 degrees to the horizontal. All lines tangent to the circle constructed about V as a center with radius VL represent possible outcrops of formation x in order to conform with the data supplied by the vertical hole. In a similar manner construct the ellipse around the slanting hole as already explained. Briefly, this is done by drawing NX and MX at 20 degrees to $S'X$.

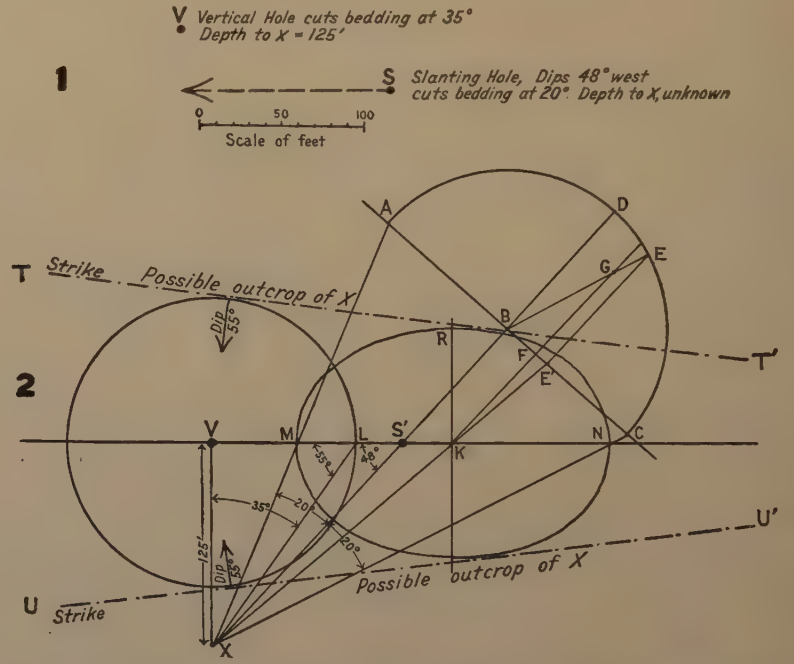


FIG. 198.—Graphic solution of problem involving vertical and slanting drill holes. The data are given in 1, the solution below in 2.

MN serves as the major axis of the ellipse. The minor axis is determined by drawing RK to K, the medial point of MN. RK is equal to FG. FG is determined by the construction demonstrated in Fig. 196. The tangent lines TT' and UU' then represent the two possible solutions of the

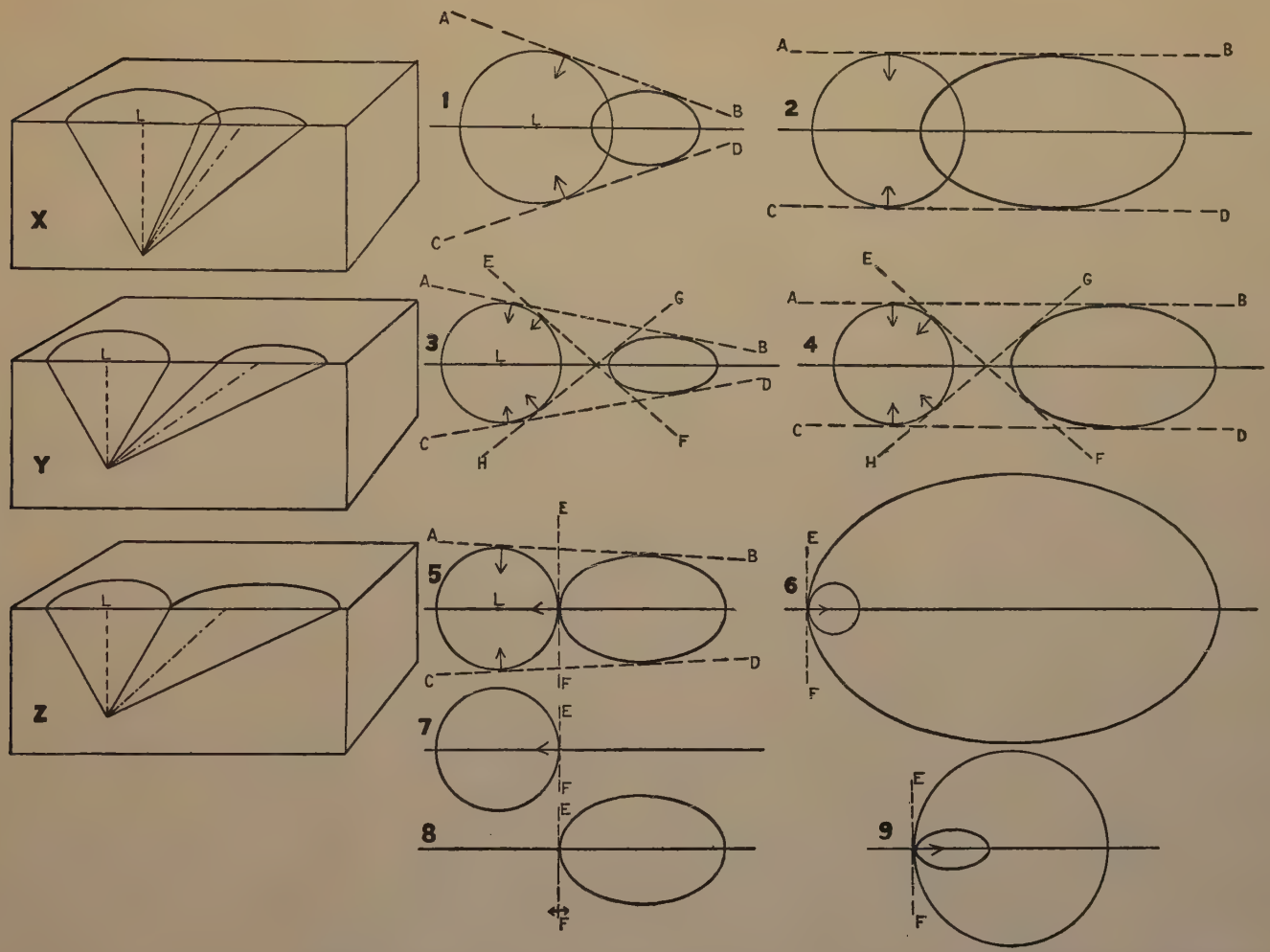


FIG. 199.—Various solutions of problems similar to the one outlined in Fig. 193. See Section 116 of the text for complete explanation.

problem, and are located properly with respect to V provided the horizontal and vertical scales of the drawing are the same.

The problem could be carried a step farther by the determination of the depth along the slanting hole in its original position S to formation x, for each of the strike solutions.

119. Problems for graphic solution.—

a. Given position of two vertical holes, and depths to formation x. Given position of slanting hole, its direction and slope and inclination of beds to the hole. Flat topography. To determine outcrop and dip of formation x.

b. Given position of vertical hole, depth to formation x and inclination of bedding to hole. Given location, direction and slope of slanting hole and depth to formation. To determine outcrop and dip of formation x.

c. Given two holes, one vertical, one slanting, and all data as to location, dip and direction of slanting hole, as well as depth to formation x in slanting hole, and inclination of beds in each hole. To find outcrop and dip of formation x.

d. Given all data as to position, dip and direction of slanting hole and inclination of bedding to the hole and depth to formation x. Given inclination of beds in any vertical hole. To find depth of any given vertical hole to formation x.

Numerous other problems of similar character may readily be devised.

120. Problems for graphic solution involving relief.— In all of the problems just explained, the surface of the ground was assumed to be a horizontal plane. It will be apparent, however, that the straight outcrop of a uniformly dipping formation on such a plane will be represented by something quite different if the topography is very irregular.

121. Problem: to determine graphically the outcrop of a tilted bed upon an irregular surface, having given its strike and dip and either (*a*) its trace upon some horizontal plane such as the sea-level plane as determined according to Section 113, or (*b*) the location of a single actual outcrop.— In Fig. 200 the strike of the formation is given. Actually its trace on the sea-level plane is given. Its dip to the southwest is known either in degrees or in feet per mile, the latter being preferable. The procedure in determining position of outcrop is as follows: At one side of the map, lay off a grid at right angles to the strike representing a cross-section of the formation. If the horizontal and vertical scales on the grid are the same, then the actual dip of the formation may be shown in cross-section. Otherwise it is more convenient to transform the known dip in degrees into feet per mile in order to plot the cross-section of the formation upon the grid. Then, from each point on the grid where the formation intersects a contour level, draw a line in the direction of the strike through the map. The points where these lines intersect the corresponding contours represent points of outcrop of the formation. Connecting these points gives a continuous line of outcrop, as shown.

This method is deemed more convenient than drawing a number of profiles at different places along the strike and determining the outcrop on each one. It also gives greater accuracy by providing a larger number of points along the outcrop than would be practicable by the other method.

122. The representation of relief by elevated contours on isometric block drawings.—Figure 201 is a topographic map of a small area with the topography expressed by means of contours. Fig. 202 is the isometric representation of this same rectangle, drawn to twice the scale. The same scale

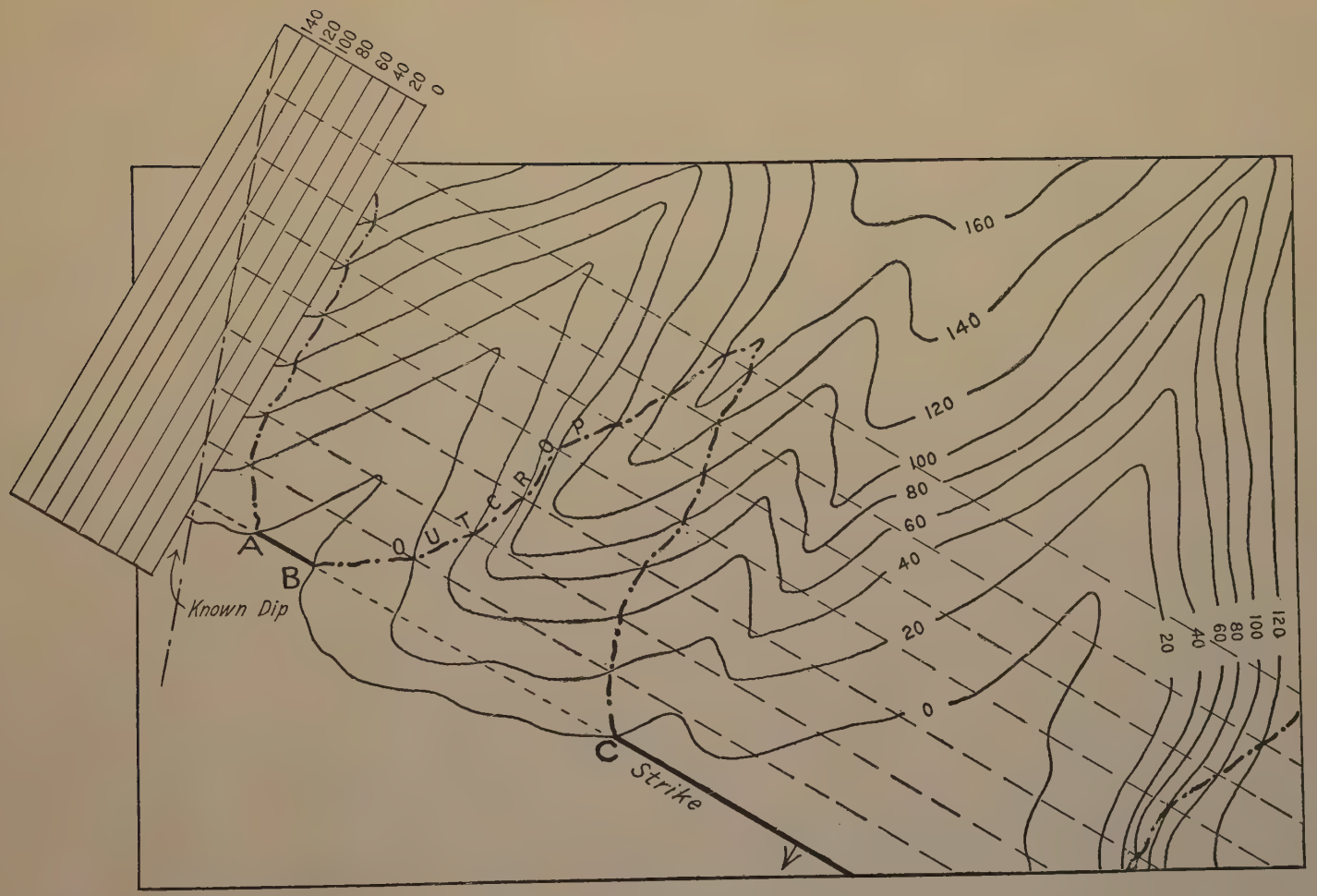


FIG. 200.—Graphic determination of outcrop in a region of relief, having given the strike and dip and actual outcrop at *A*, *B*, or *C*. Solution explained in Section 121 of the text.

or any other scale could have been used. Figure 203 is the same map redrawn on the isometric base. The procedure from now on consists in elevating each of these contours its appropriate distance above the base. Figure 204 shows a

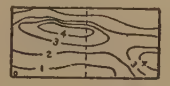


FIG. 201.—A topographic contour map of a small area. The following figures, 202 to 208, illustrate the method by which this map is enlarged and transformed into an isometric block showing the relief.

T-square attached to a sheet of tracing paper and laid over the drawing shown in Fig. 203. An arrow has been drawn on Fig. 203 to serve as a guide when the tracing paper is later moved over the drawing. Upon the tracing paper a small vertical scale has been represented, numbered 0, 1, 2,

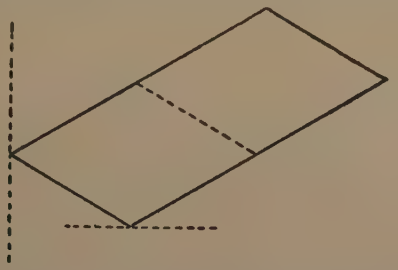


FIG. 202.—Isometric plan of rectangle shown in Fig. 201, enlarged to twice the scale.

3, 4 to correspond with the contours on the map. This vertical scale is greatly exaggerated. For various maps the most suitable degree of exaggeration may readily be determined by trial. The tracing paper, then, as in Fig. 204, is placed over the isometric drawing of the map and moved so that the

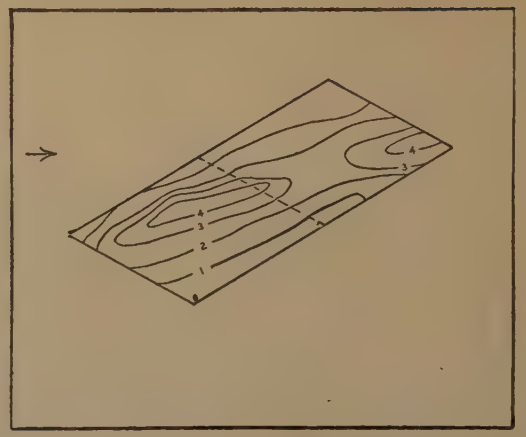


FIG. 203.—Same as Fig. 202 with the contours shown in Fig. 201 added. Additional construction lines may be used to locate position of the contours if they are very complicated and not readily drawn freehand. The larger rectangle is supposed to represent a drawing board to which the map is fastened. The arrow at the side serves as a guide in the later drawings.

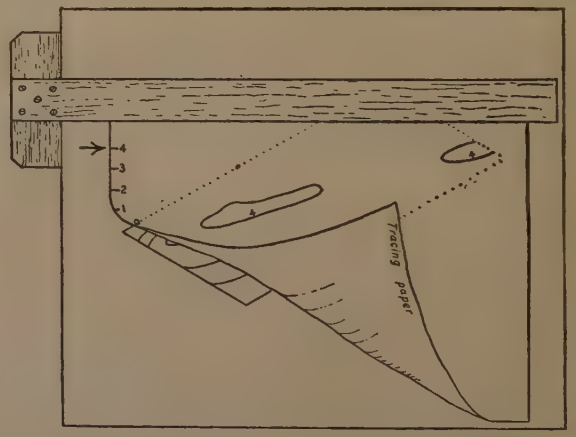


FIG. 204.—Tracing paper attached to T-square and laid over Fig. 203. The highest, or fourth, contour has been traced off. See Section 122 of text for full explanation.

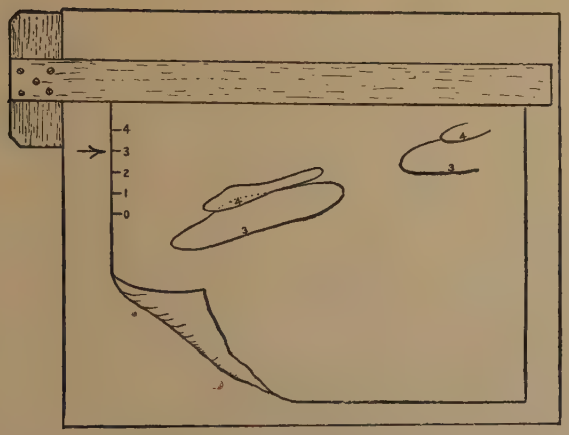


FIG. 205.—The T-square with attached tracing paper has been shifted upward one contour interval, shown by scale at the left, and the next lower (or third contour) has been traced off.

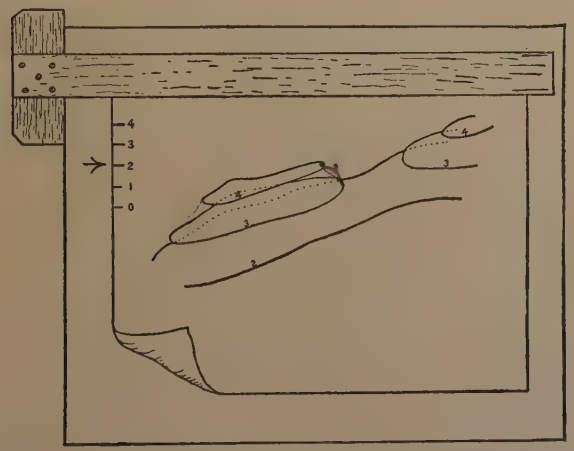


FIG. 206.—After a second shifting of the tracing paper upward, contour No. 2 is traced.

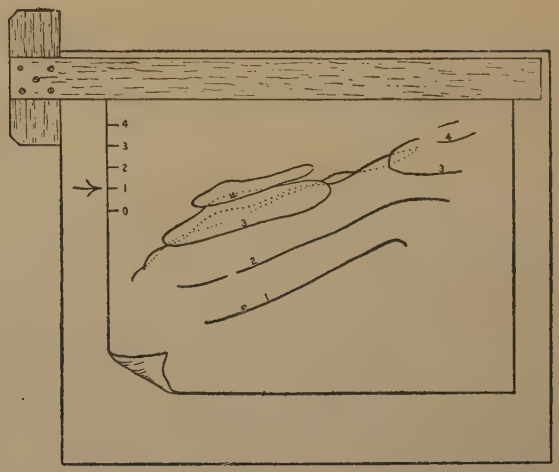


FIG. 207.—A further shifting upward of the tracing paper, and contour No. 1 is traced.

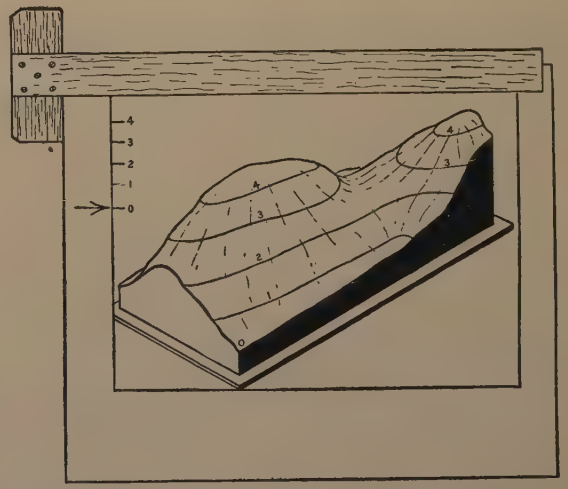


FIG. 208.—A final shifting upward of the tracing paper enables point zero to be traced. The block is then completed as shown.

arrow on the isometric drawing underneath is opposite the highest mark on the scale. In this case it is the fourth contour above zero. Upon the tracing paper, then, this contour is traced directly from the map beneath, as shown.

Figure 205 shows the next step. The T-square with the tracing paper fastened to it has been moved up so that point 3 on the scale is opposite the pointer on the map beneath. In this position the third contour is then traced. Where the third contour passes behind the fourth contour, it may be dotted as shown. Figure 206 represents the next step. Contour No. 2 has been drawn. Figure 207 represents the drawing after the tracing of contour No. 1. It will be noticed that wherever later contours pass behind earlier ones they are dotted.

In Fig. 208 the tracing paper has been moved up to zero on the scale. Zero points have been traced off and the ends of all contours have been connected to give the profile at the edge of the block. In a complex map showing roads, political lines, streams, geological boundaries, and the like, the points where these intersect the contours should be indicated upon the contour when it is traced. Thus the various points where a road, for instance, crosses the different contours may later be connected to represent the road, for there is no other way to determine its position. It is important, too, that in tracing the contours their ends should be made to terminate exactly at the edges of the map so that when they are later connected the profile forming the end or side of the block is a correct representation of the relief.

Finally, the block may be finished off by dropping verticals from each corner and completing the block according to the usual isometric methods. This has been done in Fig. 208. An additional base may be added, or any of the other devices previously suggested may be adopted. For instance, the map in the first place may be cut apart so that two blocks are drawn, thus giving more opportunity for vertical cross-sections.

123. Example of isometric block showing relief by contours.—Figures 209, 210, and 211 represent respectively a contour map, the same map redrawn on an isometric base, and the block diagram resulting from the tracing of the successive contours at appropriate elevations. It is similar to the one described under the previous section, but in addition represents a railroad line and certain survey or boundary lines indicated by dots.

124. A mechanical device for transforming a map into an isometric drawing. Dufour's method.—This device, developed by a French student,[1] has as its function the transformation of a rectangular map into the corresponding lozenge-shaped figure of the isometric drawing. It demands no more of the draftsman than the ability to trace with his pencil the contours on the map.

Figure 212 indicates the essential parts of the machine. The rectangle $ABCD$ represents the map. The lozenge-shaped figure $A'B'C'D'$ represents the map in isometric projection. Like the isometric drawings previously described this lozenge has an obtuse angle of 120 degrees. The object of the device is to reduce the length of one of the diagonals with respect to the other. Thus a long arm, ck, bears near its center a pencil, h. One end, c, traces the map, the other

[1] Dufour, M. Pierre-Th. Nouveau procédé permettant d'obtenir les perspectives-reliefs des formes géographiques représentées sur les cartes hypsométriques. Thèse présentée a la faculté des sciences de Paris pour obtenir le titre de docteur de l'université de Paris. Librairie Ch. Delagrave, Paris, 1917.

end slides in a groove, the pencil h meanwhile transforming the given square into the lozenge. A movement AC in the

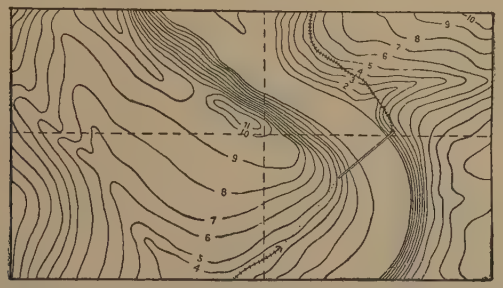


FIG. 209.—A contour map, which in Fig. 210 has been transferred to an isometric base, and in Fig. 211 to an isometric relief block.

direction of the groove produces a similar movement in the pencil, while a perpendicular movement, BD, is reduced in

FIG. 210.—Same as Fig. 209, on isometric base. In Fig. 211 the complete isometric block is shown.

the proportion $hk : ck$. The surface of the cube having been placed in perspective, it is easy to complete the drawing by the addition of the vertical lines, as shown. Thus the contours may be traced off directly with the stylus, c, and the perspective drawing automatically appears at the end of

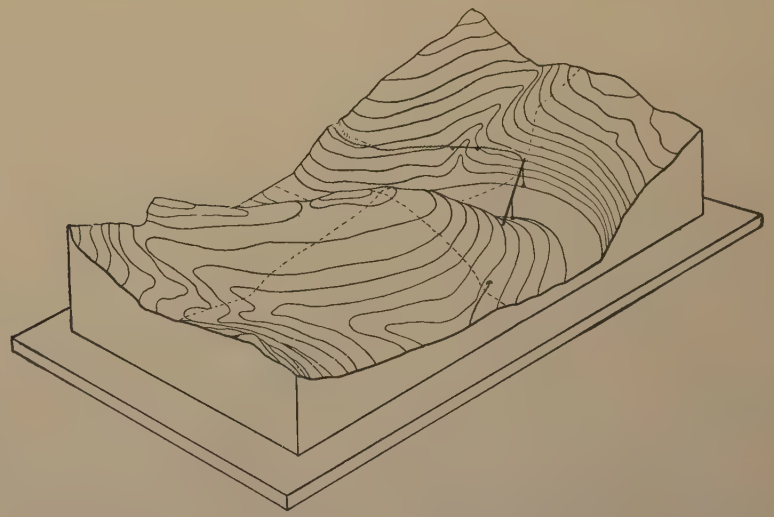


FIG. 211.—Relief block in isometric perspective, drawn from map shown in Fig. 209.

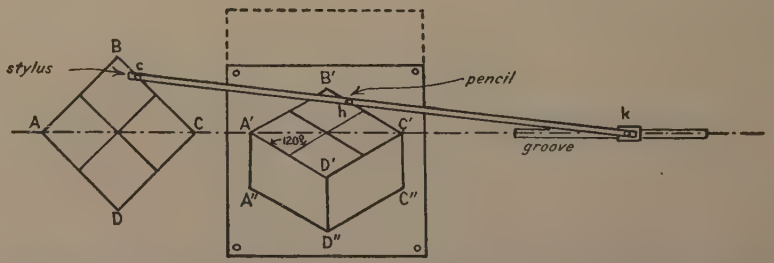


FIG. 212.—Apparatus devised by a French student, M. Pierre-Th. Dufour, to enable one to transform a map into an isometric block drawing. $ABCD$ represents the original map; $A'B'C'D'$ is the top of the resulting block.

the pencil. In tracing off each contour the perspective drawing may be moved vertically a suitable distance to allow for the contour interval. Thus one operation produces the finished drawing without necessitating the use of tracing paper as heretofore described in Section 122.

In order to change the scale of the original map, a pantograph may be affixed to the end of the long arm as shown in Fig. 213. Instead of the groove at the other end of this machine a long lever has been attached, so that the straight direction of the groove is replaced with an arc of great radius.

Consider next some of the different elements of the apparatus. The position of the pencil, h, is determined by the relation sought for between the diagonals $A'C'$ and $B'D'$ of the lozenge.

Since the angle:

$$A'B'D' \text{ equals } 60 \text{ degrees}$$

$$\frac{B'D'}{A'C'} \text{ equals } \frac{1}{\sqrt{3}} \text{ equals } \frac{hk}{ck}$$

If the arm, ck, is not very long, the lozenge $A'B'C'D'$ has somewhat the form of a kite, the lines being curved. This deformation in general is not noticeable in a perspective. It is due to the fact that a movement cB_1 (Fig. 213) which is vertical and in a straight line, corresponds to a movement of the pencil hB', which is curved, and the curvature increases with the angle through which the arm turns. In order that cB_1 and hB' shall be strictly parallel the arm ought to be lengthened in proportion to the increase of the angle through which it turns.

An additional device, however, may be used to overcome this difficulty. It consists essentially of an articulated system of rods whereby a circular movement is transformed into a rectilinear one. Note Fig. 214, which represents the device constructed from the mechanical toys now on the market.

It is constructed in such a way that the point C describes a straight line while the point A describes a circle about the fixed point E. The following conditions must hold: The point F is fixed and is situated at a distance from the fixed point E equal to AE. The two arms FB and FD must be

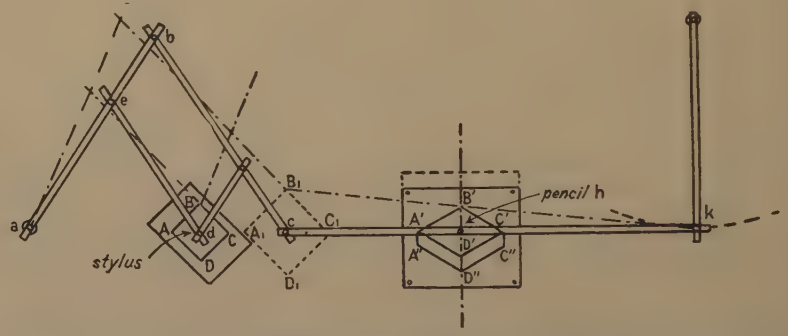


FIG. 213.—A refinement of the apparatus shown in Fig. 212, due to the addition of a pantograph which enables one to enlarge map $ABCD$ to $A_1B_1C_1D_1$ which is directly transformed into the isometric lozenge $A'B'C'D'$. A long arm has been introduced to eliminate the sliding groove at K.

equal. The four sides of the lozenge $ABCD$ must be equal. The trajectory of the point C is then a straight line perpendicular to EF.

One application of this device is the substitution of it for the swinging rod, at k (Fig. 213), the point E being pivoted vertically above k. The end k of the long arm ck will (Fig. 213) then articulate about the point C (of Fig. 214) and will have a movement identical with that of the groove first mentioned.

The chief value of this device, however, is that it enables

one to avoid the rigid arm which, even though long, gives a curved motion to the pencil when the stylus follows a straight line on the map. It is only necessary to add to the device just described (Fig. 214) the two articulated elements GH and KH parallel to BC and CD and articulated at the points G and K on the long bars in such a way as to satisfy the relation:

$$\frac{FG}{FB} \text{ equals } \frac{FK}{FD} \text{ equals } \frac{1}{\sqrt{3}}$$

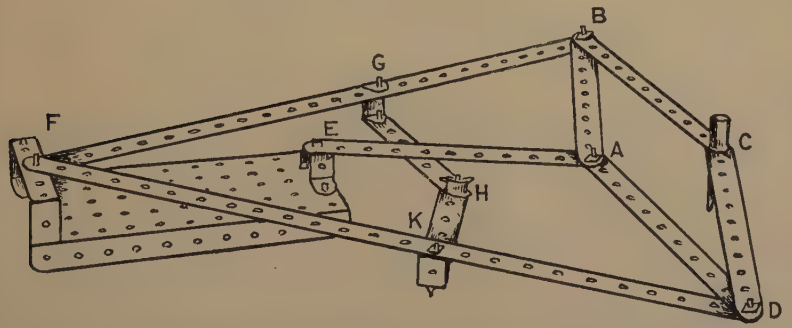


FIG. 214.—A special device described in Section 124 of the text, which enables one to avoid several slight difficulties met with in the use of the simpler devices shown in Figs. 212 and 213.

The triangles FGH and FBC are similar for all positions, for the points F, A, and C are constantly in a straight line. Substitute now for the long arm in Fig. 213 this articulated system, Fig. 214; the point C will correspond to the point c carrying the stylus; H to h carrying the pencil. The axes of rotation F and E will remain fixed with relation to each other but will slide in the groove in the direction $A'C'$ of Fig. 212. The point F then plays the part of the point k.

The point C may now describe a straight line perpendicular to the groove and it will cause the pencil H to follow a course strictly parallel but reduced in the proportion $\frac{1}{\sqrt{3}}$. This is the condition which must be filled in order to trace an isometric perspective. The points F, H, and C between them constitute the equivalent of a long arm which may be extended and also frees us of the necessity of using a very long arm swinging in a small angle. But even without this apparatus very satisfactory drawings may be produced with the use of the device first described.

In addition to the apparatus here described, the paper by Dufour suggests and illustrates the preparation of isometric block drawings for use with the binocular stereoscope. It is only necessary to make two separate drawings from slightly different points of view. That is to say, after one drawing is made, the map is turned at a slight angle and the other drawing made. The two are then used together in the stereoscope. The result appears satisfactory, but distinct artistic skill would seem to be almost indispensable to a proper representation of the details, which must necessarily be very nearly but not quite the same in the two drawings.

125. Applications of the isometric projection in the presentation of geologic facts or ideas.—There are numerous applications of the isometric drawing in the presentation of facts in which the quantitative element is important. The isometric block makes it possible to represent to scale the thickness of formations on the top, sides, and ends of the block, and to show correctly the dip of the beds. Even though it is not possible to read thickness of beds, dip, or strike, directly from the drawing, at least it is an extremely simple matter to transform the corresponding part of the block into undistorted cross-section or map, or vice-versa. Because all these facts are correctly represented on the block,

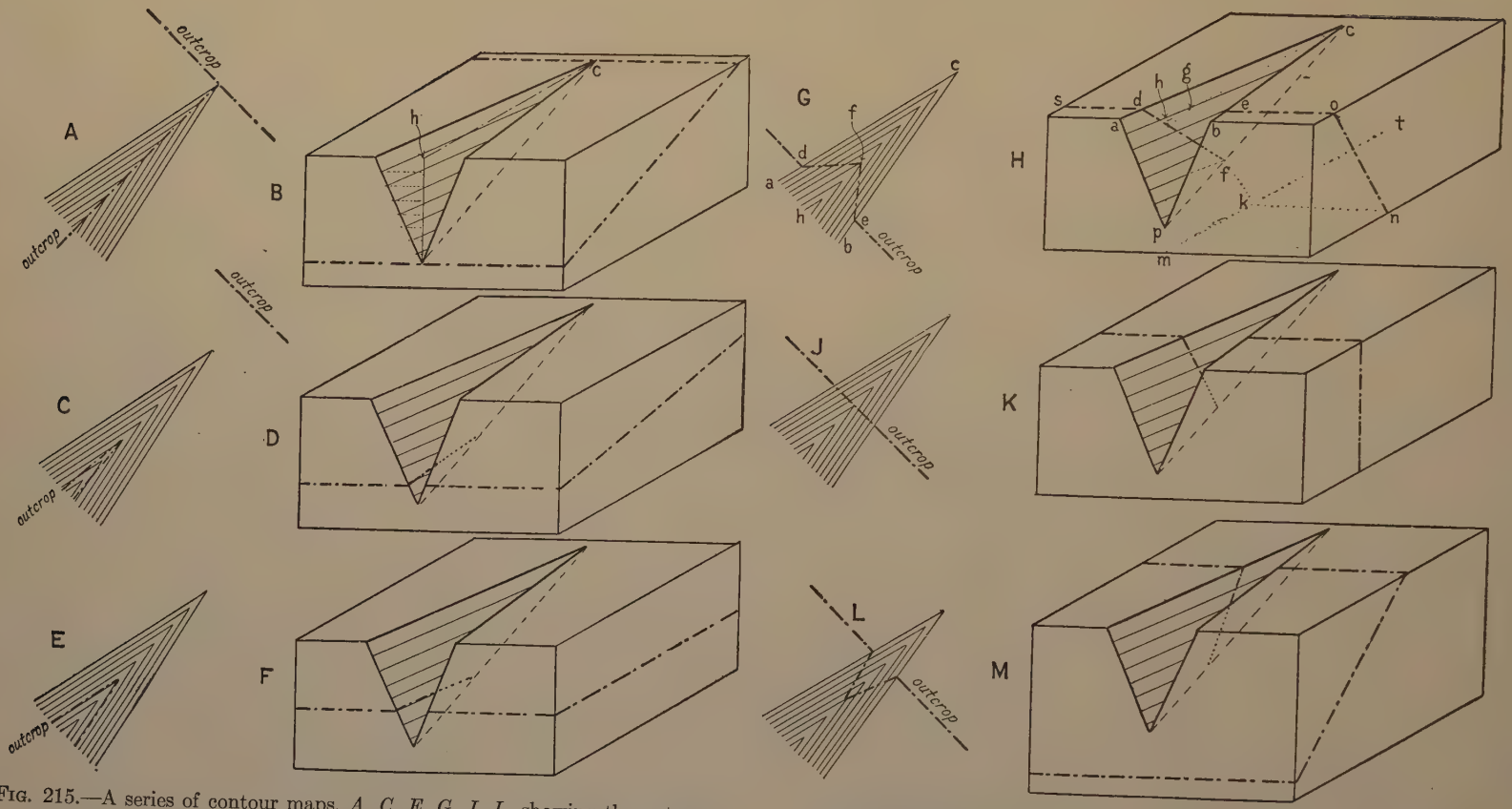


FIG. 215.—A series of contour maps, *A*, *C*, *E*, *G*, *J*, *L*, showing the outcrop of a formation with a given strike normal to the direction of the valley but with varying dips in the different cases presented. For instance, in *A*, the formation has a dip equal to the slope of the stream; in *C* the dip is less than the slope of the stream; in *E* the formation lies horizontally; in *G* the formation dips upstream; in *J* it is vertical; and in *L* it dips downstream, but more steeply than the slope of the stream. The isometric blocks at the right show in each case the facts given on the contour maps.

problems may be worked out in a graphic manner in order to determine what the results of certain conditions are. For instance, what is the surface extent of a formation 100 feet thick, dipping 20 degrees to the southeast, if beveled by a horizontal plane? How will this formation appear in a canyon wall the sides of which slope 25 degrees, the stream cutting directly across the strike of the beds? How does faulting with later planation affect the surface outcrop of folded or tilted beds? All problems in which the three-dimensional aspect is important lend themselves to this treatment. The isometric block, therefore, is useful not only in aiding the visualization of three-dimensional masses but it is equally valuable in solving questions which could not be worked out readily and accurately by the true one-point or two-point perspective.

126. The outcrop along the valley walls of a dipping bed whose strike is normal to stream.—Figure 215 presents a series of contour maps representing a valley, and a corresponding series of block drawings illustrating in isometric perspective the facts presented by the maps. The uppermost block, *B*, shows the formation dipping downstream with a dip equal to the gradient of the stream and outcropping everywhere in the bed of the stream. In the successive blocks the dip of the formation is changed but the strike remains normal to the stream. In block *D* the dip is less than the slope of the stream, in block *F* it is horizontal, in *H* it is between horizontal and vertical, in *K* it is vertical, and in *M* the dip is again downstream but greater than the slope of the stream. It will be noted that in each case the formation outcrops in the bed of the stream where it is crossed by the third contour, this being done so that a comparison may be made between the different drawings.

The drawing of the blocks in isometric perspective is readily accomplished, but several construction lines are necessary. This is illustrated in block *H*. At first the main outline of the block is laid out. The notch is drawn so that its medial line *hc* is parallel to the sides of the block. The line, *hm*, of course, is vertical. The points *a* and *b*, equidistant from *h*, are connected with *c* and with *p*. The contours on the visible side of the notch are drawn parallel to *ac* and may be measured off to any true vertical scale as shown in block *B*. To draw in the formation, indicate *so*, its outcrop on the surface, this line being parallel to the front of the block. From *g*, where *so* cuts *hc*, draw *gfk* through *f*, the point in the stream where it is decided to have the formation outcrop, to *k* on the line *mt* which is parallel to *hc*. The point *f* is determined by the intersection of the third contour with *pc*. Then draw *kn* parallel to *so*. This gives the point *n*, which may now be connected with *o* to show the formation at the side of the block. Connect *df* to show the outcrop of the formation on the valley wall. Thus every line in the drawing is accurately determined. No artistic eye is required at any point unless it be to decide in the first place what the tilt of the block shall be and what position the notch shall have in it. The whole procedure is mechanical.

EXERCISES

Based upon the Illustrations in Part II

Exercise 1. Draw an isometric projection of A in Fig. 177, with angles of 45 degrees and 135 degrees at the corners, instead of 60 degrees and 120 degrees as shown in block B of Fig. 177.

Exercise 2. Draw an isometric projection of A, Fig. 177, with the front of the block, *abef*, undistorted. Use any convenient angles on the top of the block.

Exercise 3. Draw an isometric projection of A, Fig. 177, with all angles on top of the block 90 degrees. The front of the block, *abef*, however, must not be horizontal.

Exercise 4. Select some point on top of block ~~A, Fig. 178~~. Determine corresponding position for same point in ~~blocks B~~ and C.

Exercise 5. Using Fig. 182 as a basis, show graphically the plane of formation x, and its strike and dip (extending the block if necessary), if hole B is only 250 feet deep instead of ~~310~~, to formation x. All other data remain the same.

Exercise 6. Repeat Exercise 5, changing the depth of hole C to 480 feet, instead of 390 feet, keeping all other data as in ~~the original problem~~.

Exercise 7. On ~~Fig. 182~~ or ~~Fig. 183~~, select some point between A and B. How far below sea level is formation x at this point? Show construction lines.

Exercise 8. On ~~Fig. 182~~ or ~~Fig. 183~~, select some point within the triangle $A'B'C'$. How far below sea level is formation x at this point? Show construction lines.

Exercise 9. Using Fig. 186 as a basis, determine strike and dip if hole B is only 250 feet deep, instead of 310 feet, to formation x, all other data remaining the same. Compare with result of Exercise 5, above.

Exercise 10. Using Fig. 187 as a basis, repeat Exercise 9. The result should be the same.

Exercise 11. Using Fig. 186 as a basis, determine strike and dip if hole C is 480 feet deep, instead of 390. Keep all other data as given.

Exercise 12. Using Fig. 187 as a basis, repeat Exercise 11. The results should be the same.

Exercise 13. Following the method used in Fig. 188, determine dip and strike if hole C goes 400 feet, instead of 310 feet, below sea level before piercing formation x. Fig. 188 is on the same scale as Figs. 179–187.

Exercise 14. Using method described for Figs. 190, 191, and 192, determine true strike of formation if slanting hole B goes down 80 feet, instead of 40 feet, before piercing plane of formation. All other data remain the same.

Exercise 15. Using same plan as Fig. 190, determine strike and dip as well as outcrop, with the following data: hole A is 60 feet deep; hole B slants 55 degrees to horizontal in a direction S 45 degrees E, and is 100 feet deep; hole C slants 45 degrees to horizontal in a southerly direction and is 90 feet deep.

Exercise 16. Devise other problems by altering the figures given in Exercise 15.

Exercise 17. Prepare an isometric block, such as Fig. 189, 2, illustrating all the lines used in Fig. 192.

Exercise 18. Using the construction methods of drawing ellipse formed by intersection of plane with cone, as given in Fig. 196, show that KR would be the same if the circle ADC were larger, that is if the distance BX were longer.

Exercise 19. Using Fig. 196 as a guide, determine other lengths, similar to KR, erected vertically at other points along the line LN.

Exercise 20. Using the suggestions given in Section 119, assign values for all the known data in the four problems and then solve the problems graphically.

Exercise 21. Make up one more type of problem similar to those proposed under Section 119.

Exercise 22. Using Fig. 200 as a basis, determine position of outcrop if the dip is doubled in degrees, the strike direction and the points A, B, and C remaining the same.

Exercise 23. Repeat previous exercise with dip one-half of that given in Fig. 200.

Exercise 24. Using Fig. 200 as a basis, determine outcrop if the strike is east-west, the point C remaining stationary and the dip as originally given but toward the south.

Exercise 25. Using Fig. 200, plot outcrop of a formation 20 feet below the one given, measured normal to bedding planes.

Exercise 26. Repeat for a similar formation 20 feet above.

Exercise 27. Using Figs. 201 to 208 as a guide, prepare an isometric relief block of Fig. 201, separated along the dotted line to show a cross-section through the middle of the block. Draw diagonals or other similar straight lines across the map shown in Fig. 201 and represent these on your finished drawing also, determining exactly where each one crosses a contour in order to do so.

Exercise 28. Select some small and suitable area involving geological structure and surface formations, roads and political lines and relief by contours. Represent the region by isometric block drawing as in Figs. 208 or 211.

Exercise 29. Introduce on Fig. 211 geological structure, showing horizontal formations. Color sections and surface outcrops. Select formations of various thicknesses and types of rock.

Exercise 30. Transform Fig. 200 into an isometric block. Indicate outcrop on surface and show cross-section of structure.

Exercise 31. Prepare a series of maps and blocks similar to Fig. 215, to show various outcrops on the valley wall depending upon the dip of a formation whose strike is (*a*) parallel to direction of stream; (*b*) parallel to direction of contours in one valley wall; (*c*) intermediate between direction of strike and contours on one valley wall; (*d*) intermediate between direction of contours on valley wall and normal to stream direction. These problems, although presenting arbitrary situations, provide splendid practice in visualizing geologic structure.

Exercise 32. Devise and prepare a block showing three parallel formations each 50 feet thick, dipping south 25 degrees, cut by a vertical fault parallel to the strike, the northern side uplifted 75 feet; the whole area then planed off to original elevation. This problem offers several solutions depending upon location of the fault with reference to outcrop of formation.

Exercise 33. Prepare one or more isometric blocks to illustrate the terms descriptive of faulting, referring to Leith's "Structural Geology," and to Reid, Davis, Lawson, and Ransome in Bull. Geol. Soc. Am., vol. 24, pp. 163–186, 1913.

Exercise 34. In an exposure on a level surface, a stratum shows a dip of $22\frac{1}{2}$ degrees. How deep will this stratum be at a distance from the exposure of 400 feet in the direction of dip?

Exercise 35. A rock bed at the base of a formation dips 45 degrees to the north. The top of the formation is found 820 feet distant in the direction of dip. The surface is level. How thick is the formation?

Exercise 36. A formation shows a dip at its base of 30 degrees in a direction N 15 degrees W. The top of the formation is found at a distance of 900 feet in a direction N 45 degrees E from the exposure of the base. The surface is level. How thick is the formation?

Exercise 37. A narrow coal seam shows in an outcrop a strike N 45 degrees E, dip 30 degrees NW. At what distance due north will the seam be 150 feet deep?

Part III

SPECIAL METHODS AND THE MORE ELABORATE TYPES OF DIAGRAMS

127. Transformation of topographic maps into block drawings by raising certain specific points to their correct elevation above the block.—One of the topographic maps of Switzerland (Aletschgletscher sheet, No. 493, scale 1 : 50,000) is selected to demonstrate this method. The region is highly complicated with peaks and disordered topographic forms. The first step is to lay out a block, shown in Fig. 216. This block may be drawn in isometric, two-point, or one-point perspective. Fig. 216 is represented in one-point perspective. On the surface of the block, as shown in the foreground, indicate in pencil the position of points whose elevations are given on the map. Then, as in the back half of the drawing, erect perpendiculars above these points in accordance with an adopted vertical scale. This scale may be selected by trial, but usually would have an exaggeration of two to five times the horizontal. Figure 216 will suggest the approximate number of points which should be treated in this manner. These points are then used as a guide in drawing the relief. In Fig. 216 some of the relief is outlined, use being made of the points at the top of the appropriate vertical lines. In Fig. 217 the complete area is represented in relief and the vertical lines and other structural lines are erased.

128. Transformation of large-scale topographic map into a relief drawing without the use of the block.—In Fig. 218, which corresponds with Fig. 216, and which represents a portion of the same area, vertical lines have been raised above the given points without transforming the map into a block. The points, with the figures representing their altitudes, may be traced directly from the map, or the map may be placed over the sheet of paper on which the drawing is to be made, and the points pricked through with a needle. After the map has been removed, the altitudes of the given points may be indicated in pencil beside the prick marks, as in the foreground of Fig. 218. Vertical lines are then drawn, as in the back part of Fig. 218 and the relief sketched in as before. Figure 219 represents the completed drawing made in accordance with this method. The advantages which this method has over the one used for Fig. 217 are several. The labor of transforming the map into a block is avoided, for the points can be traced directly from the map. Moreover, the distances in different directions are the same in all parts of the drawing, slight allowance being made for differences in relief.

It may be suggested that, in general, when the method

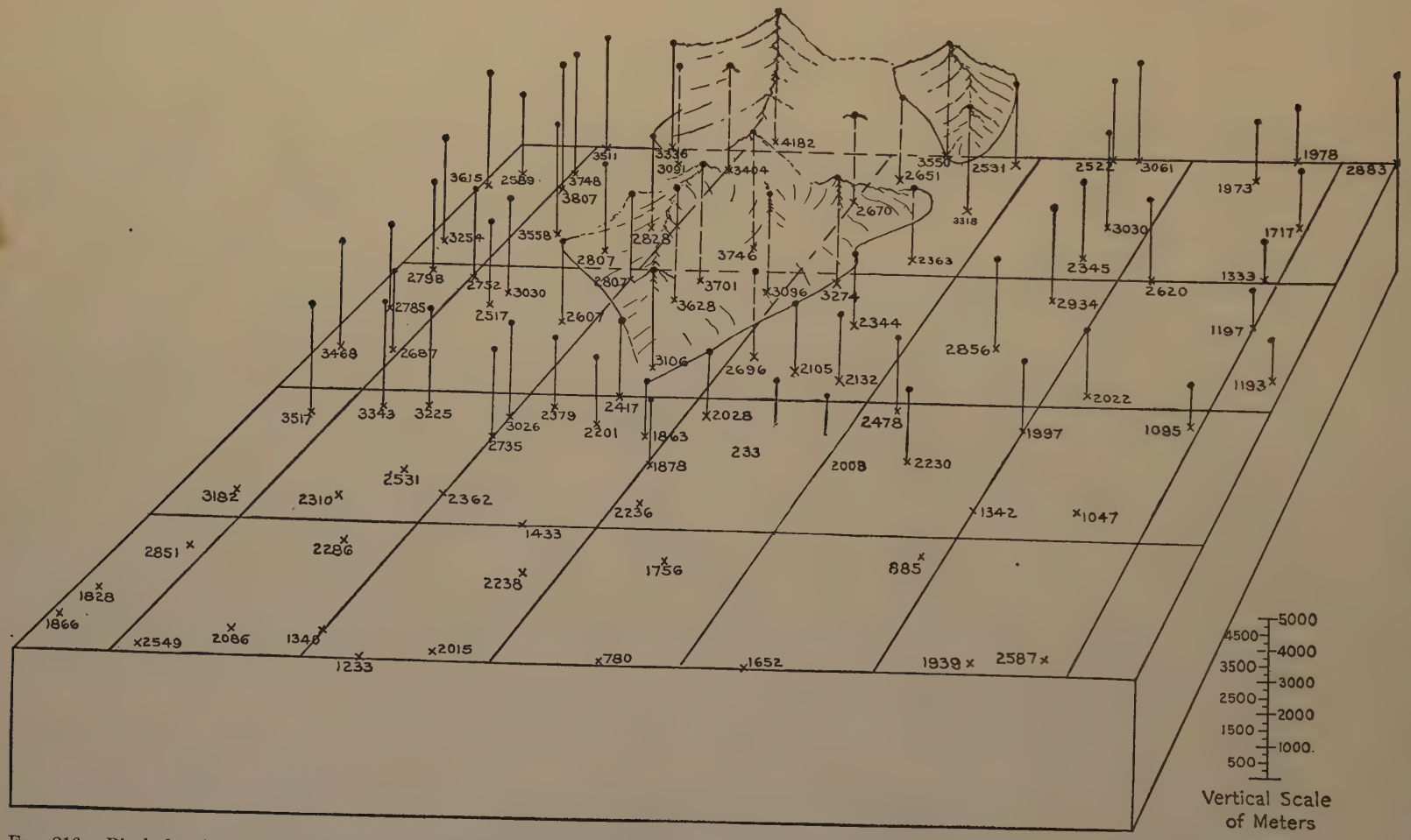


FIG. 216.—Block drawing in preparation for presentation of Aletschgletscher sheet, No. 493, map of Switzerland, scale 1 : 50,000. The map has been transformed into a block drawn in one-point perspective. Points on the map have been transferred to the block with the figures representing their altitudes. In the back part of the block vertical lines have been raised above these points in accordance with an adopted scale in order to establish the actual position of these points in space. Part of the topography has been sketched in, use being made of the appropriate points.

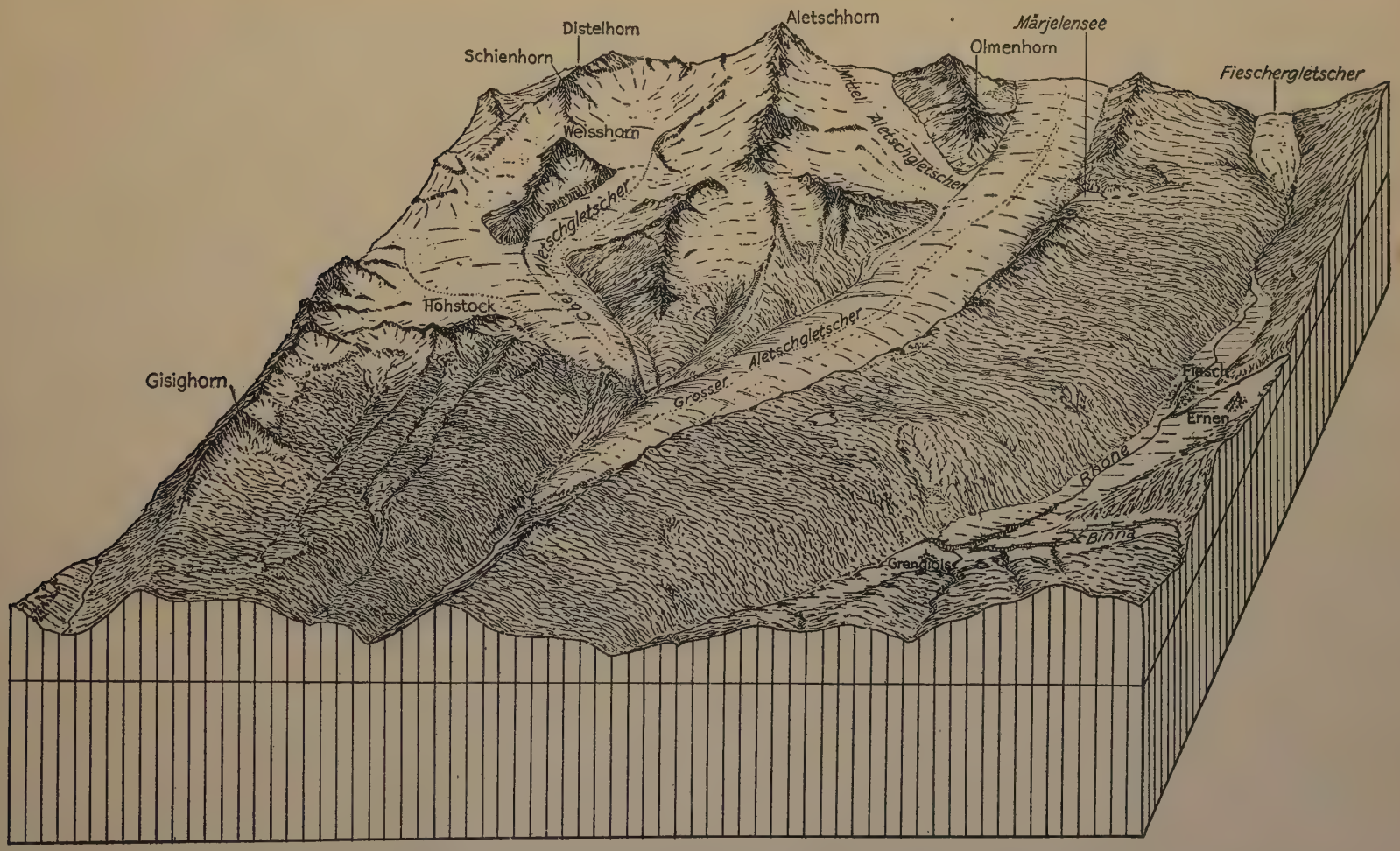


FIG. 217.—The same block shown in Fig. 216 with topography completed and construction lines erased. Aletschgletscher sheet, No. 493, map of Switzerland, 1 : 50,000.

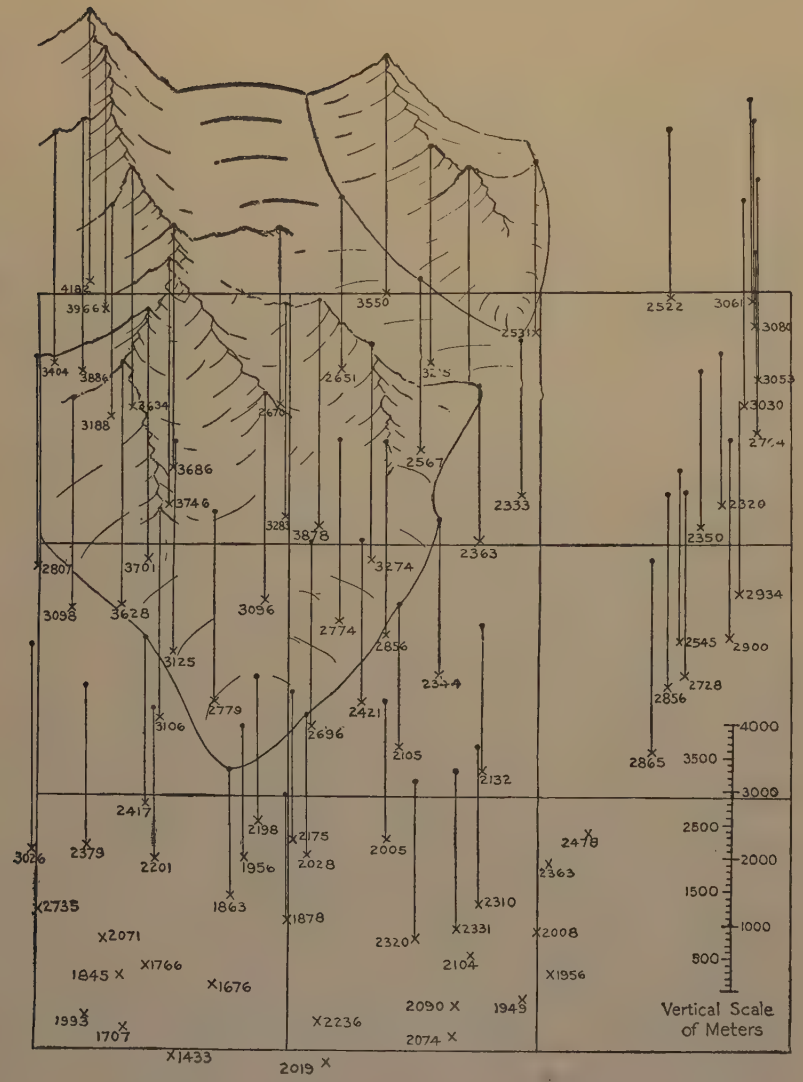


FIG. 218.—Part of area shown in Fig. 217. Instead of a perspective block the map itself is used as a base above which the points are projected.

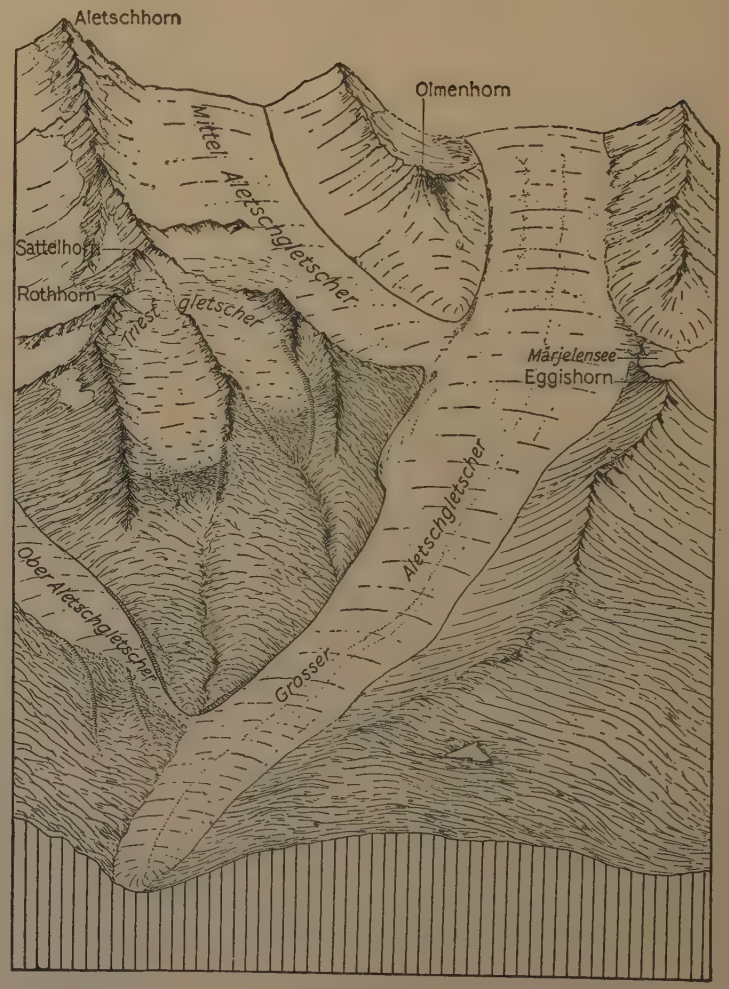


FIG. 219.—Same as Fig. 218 with completed topography. Part of Aletschgletscher sheet No. 493, map of Switzerland, 1 : 50,000.

described in this and the preceding sections are used the highest parts of the area should be in the rear of the block. The drawings of the eastern Alps on the inside covers of this book were prepared by a method only slightly different from the ones here described.

129. Transformation of small-scale maps into relief maps or diagrams. Comparison of relief maps with true block diagrams.—For large areas, where it is desirable to retain the general form of a map with a scale everywhere the same, and to suggest also the topography as if seen from a high vantage point, it is possible to take the outlines from the map and then sketch in the topography more or less in accordance with the principles already laid down in the first chapters of this book. Figs. 220 and 221 present parts of Europe and North America thus treated. The distinction between different geological areas is made possible by various kinds of shading, ruling, or stippling. Crystalline areas are best represented by crinkly lines, drawn freehand. Sedimentary areas of consolidated rocks are shown by horizontal ruling. The lower areas are best drawn by close ruling or by darker stippling.

Figure 222 represents part of the eastern United States on a still larger scale. On this larger scale, even without cross-sections, the geological structure can be suggested, as has been done very definitely in central Pennsylvania. The cuestas in the Adirondack region and in New Jersey, and the trap ridges of the Triassic Lowland all have their structure sharply portrayed. Moreover, if it is found desirable, geological sections may be introduced by cutting out strips of country. Usually, however, if it is desirable that the geological structure be shown in any detail, the true block diagram will be found more suitable than the map.

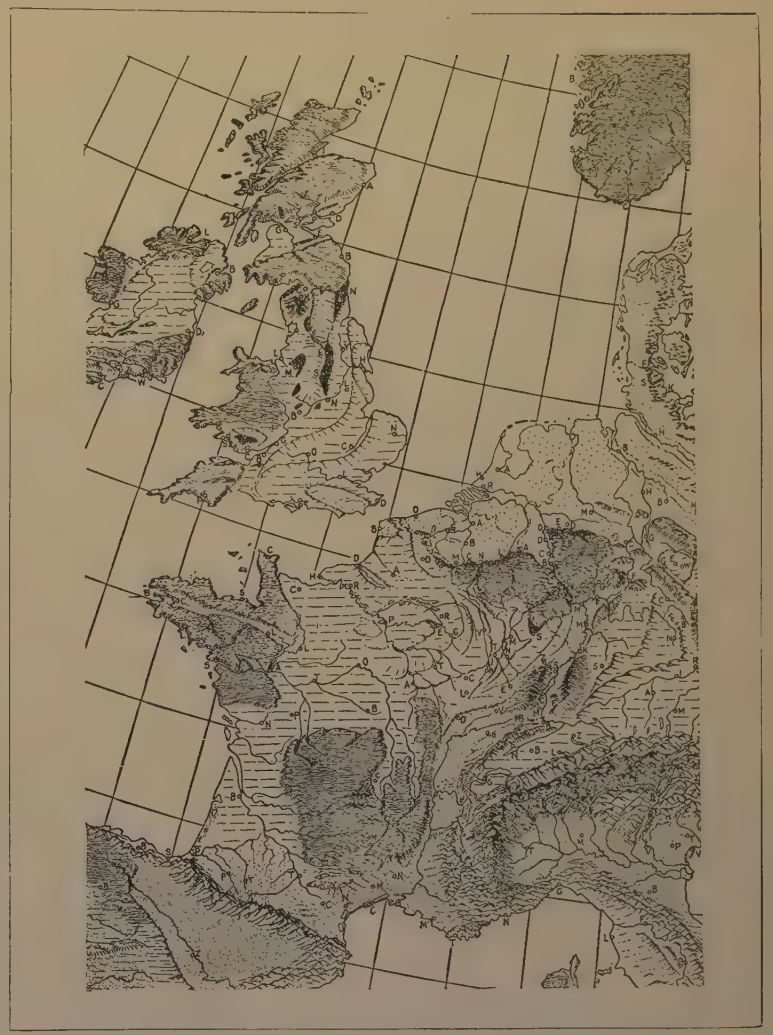


Fig. 220.—Part of small-scale Physiographic Diagram of Europe.

FIG. 221.—Part of small-scale Physiographic Diagram of United States.

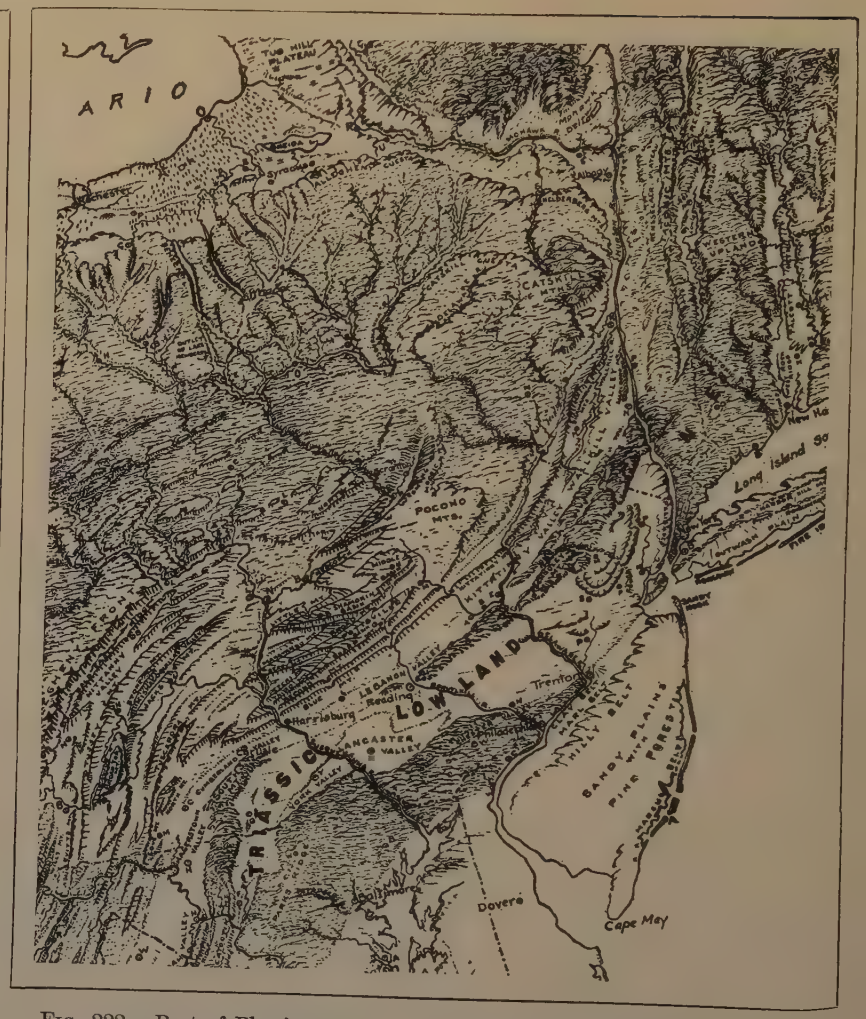


FIG. 222.—Part of Physiographic Diagram of United States on a scale more detailed than in Fig. 221. Compare the northern New Jersey portion with the next figure. (Permission of A. J. Nystrom & Co.)

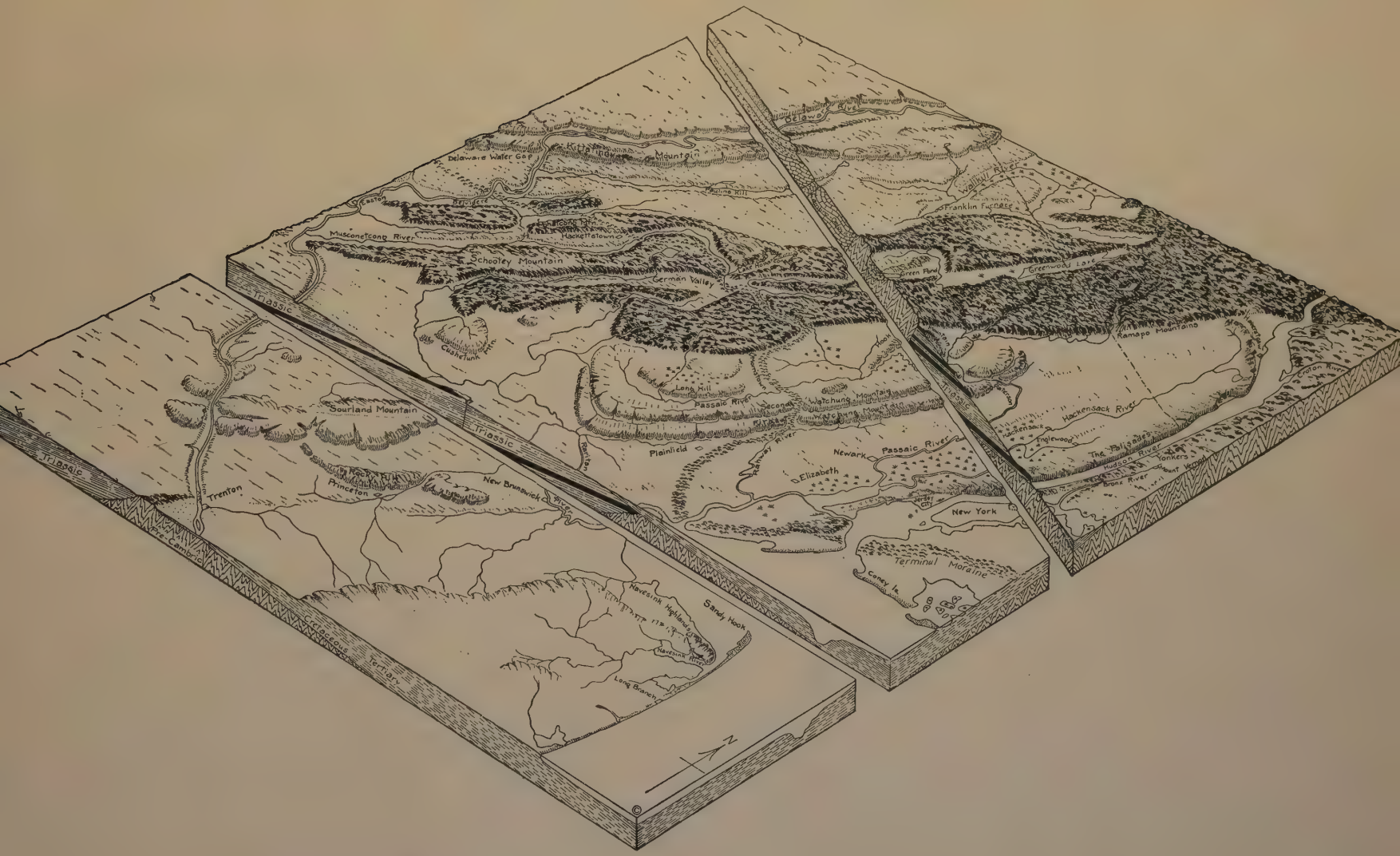


FIG. 223.—Block diagram of northern New Jersey, showing in block form part of the area represented in the preceding figure on a map base. The block has been turned so that both east-west and north-south geological cross-sections can be seen. It is impossible to show both east-west and north-south cross-sections on a map base from the same point of view. Moreover, if sections are wanted on a map diagram like Fig. 222 it is practically necessary to omit some of the topography to make room for the section. (Permission of N. Y. Academy of Sciences.)

A few comparisons between the map diagram and the block diagram will bring out more clearly the characteristics of each. Figure 222 shows in map form the topographic features of the northeastern United States by means of diagrammatic symbols. In Fig. 223 part of this area is presented as a block diagram with several sections showing the geological structure. The distortion of the geographical features in Fig. 223 may at first be objectionable after the map diagram has been used. It will be noted in Fig. 223 that the north-south and east-west directions conform to the sides of the diagram so that it is possible to represent north-south geological cross-sections. This can never be done on a map diagram like Fig. 222 without changing the point of view, and then the value as a map is to some extent lost.

Figure 224 is similar to Fig. 222 and represents on a map base some of the features of the southern United States. This may be compared with Fig. 225, which shows in detail the topography and structure of the Chattanooga district. The important structural sections here are the east-west sections. These could very readily have been placed on a map like Fig. 224, were it of sufficiently large scale. However, the topography is represented more pleasingly on Fig. 225. This is because the features have a linear trend and in Fig. 225 this trend is across the line of sight, permitting a proper effect of foreshortening, whereas in Fig. 224 this is not possible.

Figure 226, taken from the Physiographic Diagram of the United States, is similar to Figs. 222 and 224 in having a map as its base. It represents the Colorado Plateau and adjacent parts of the United States. Compare this figure with Fig. 227 which represents in block form the Colorado Plateau province. In Fig. 227 several geological cross-sections are

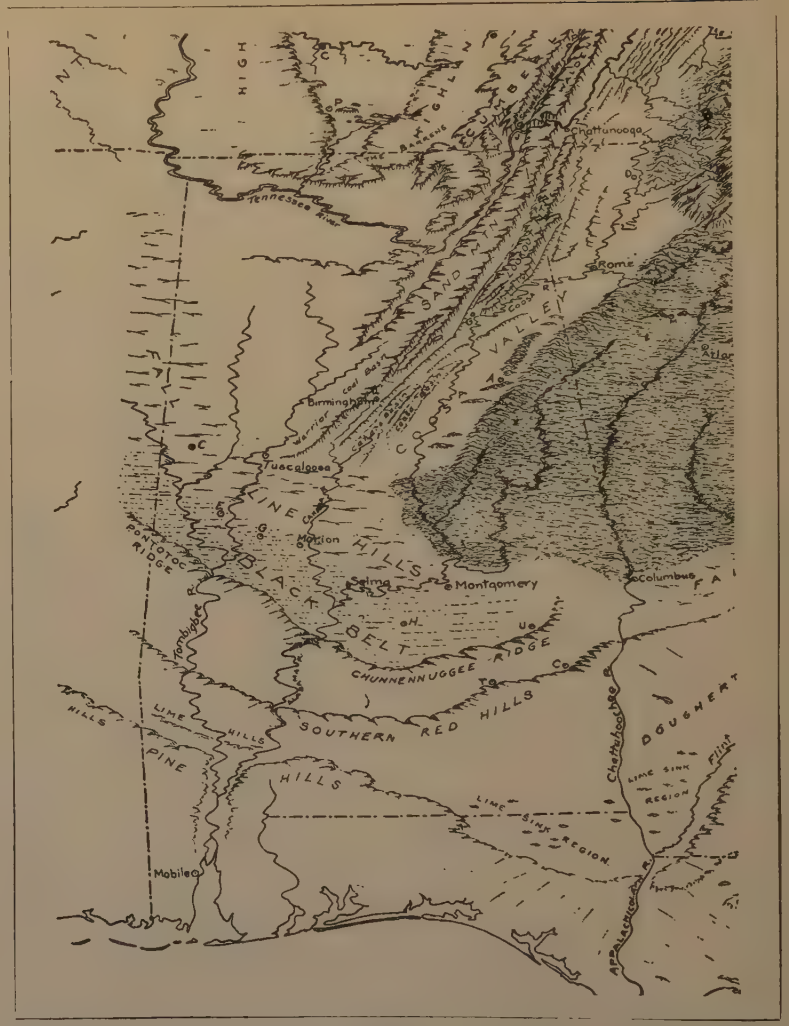


FIG. 224.—Physical features of Alabama, from large-scale Physiographic Diagram of the United States. Compare the Chattanooga region as shown here with the following figure. (Permission of A. J. Nystrom & Co.)

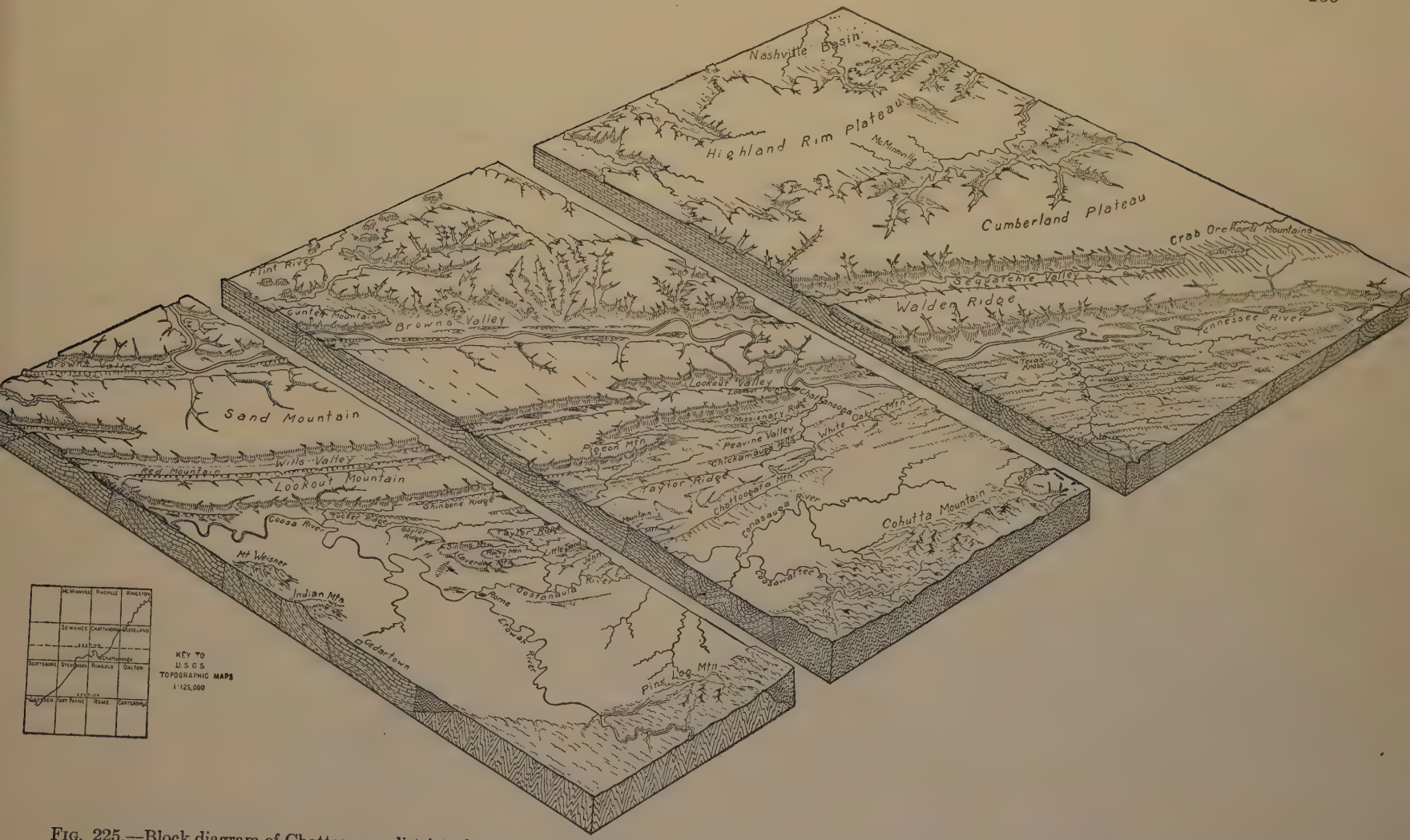


FIG. 225.—Block diagram of Chattanooga district, showing in block form part of the area which is represented in Fig. 224 on a map base. This diagram is based upon topographic maps and folios of the United States Geological Survey.

FIG. 226.—Part of large-scale Physiographic Diagram of the United States, showing physical features of Colorado Plateau and adjacent regions. Compare with the following figure. (Permission of A. J. Nystrom & Co.)

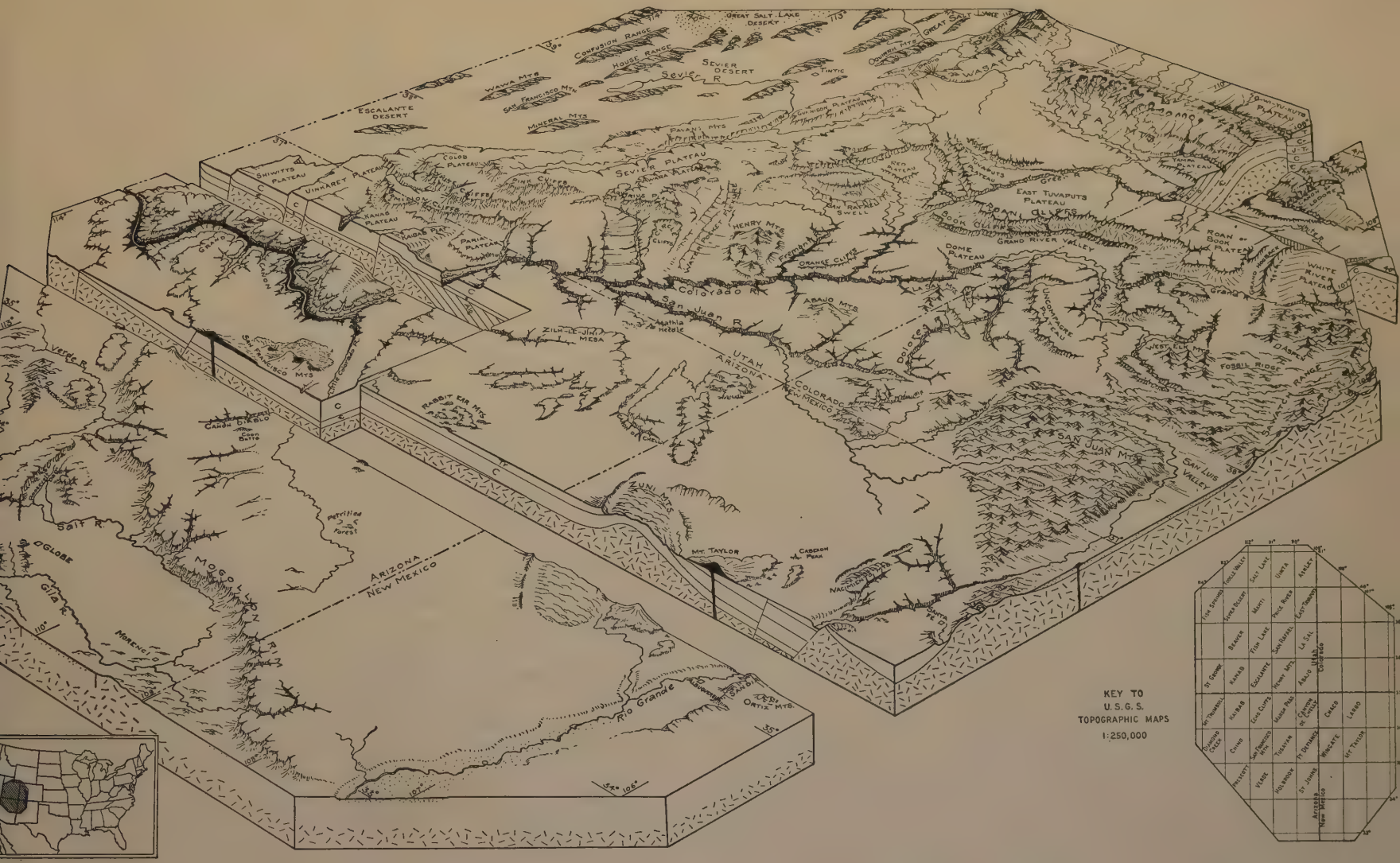


FIG. 227.—Block diagram of Colorado Plateau province, showing in block form part of the area which is represented in the previous figure on a map base.

introduced and the block is pulled apart in several places. It is not practicable to treat a map in this manner.

Fig. 228.—Block diagram of Poland and adjacent districts. The distortion of geographic features is so slight in this case that the drawing bears a strong resemblance to a map. (By permission of Henry Holt & Co.)

A somewhat simpler type of drawing, intermediate between a detailed block diagram and a map diagram, is shown in Fig. 228. This drawing might almost as well have used the map as a base, even though the distortion of geographic features is slight. The east-west cross-section in the foreground could have been introduced into the map, but the north-south cross-section along the eastern edge of the block could not have been shown on a map.

The sketch of Albania in Fig. 229 is in the form of a block but no geological structures are shown. The excuse in this case for using a block is that the mountain ranges trend north and south so that a map view would not permit the representation of the ridge profiles.

Professor W. M. Davis, in his "Handbook of Northern France," uses a diagrammatic type of map very effectively. Two examples are shown in Figs. 230 and 231. Figure 230 adopts ruled symbols for different physiographic and geologic areas. The cuestas are distinguished by short hachures, which readily convey the idea of relief. In Fig. 231 a less formal and less diagrammatic method is used, so that the relief has a more natural appearance.

130. Physiographic maps and regional diagrams.—The representation of natural regions, physiographic divisions, or geologic areas can often be suitably accomplished by some sort of flat map or diagram rather than by a bird's-eye view. Figure 230 is essentially of this type. In Bowman's "Andes of Southern Peru," a special type of regional diagram is developed. The symbols used suggest the relief as well as certain geographic responses.

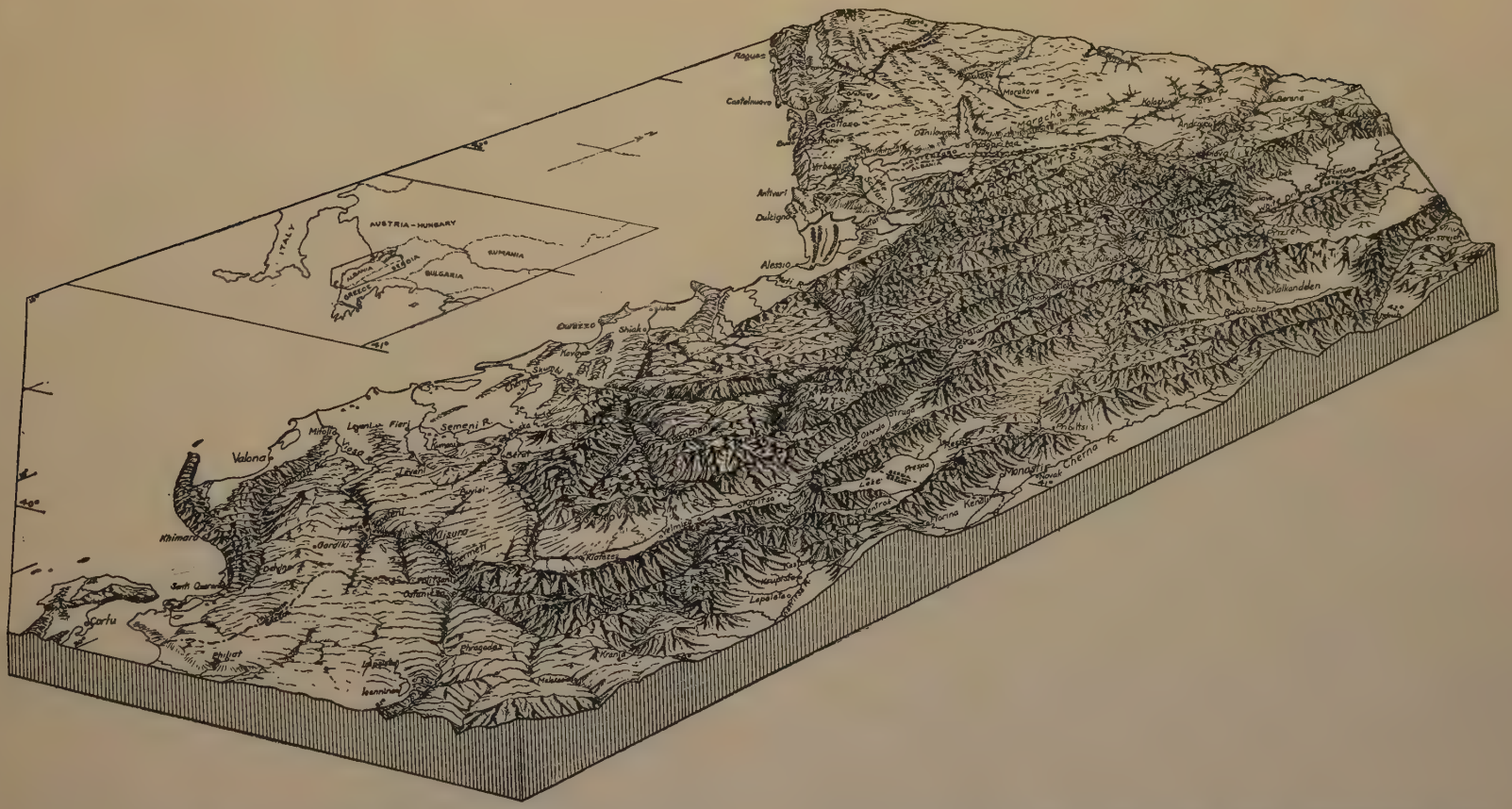


FIG. 229.—Block diagram of Albania. While no geological structure is shown, it is considered advisable in this case to use the block form rather than to base the features upon a map, because of the north-south trend of the ranges which ought to run across the line of vision in order that the ridge profiles may be represented. (By permission of American Geographical Society.)

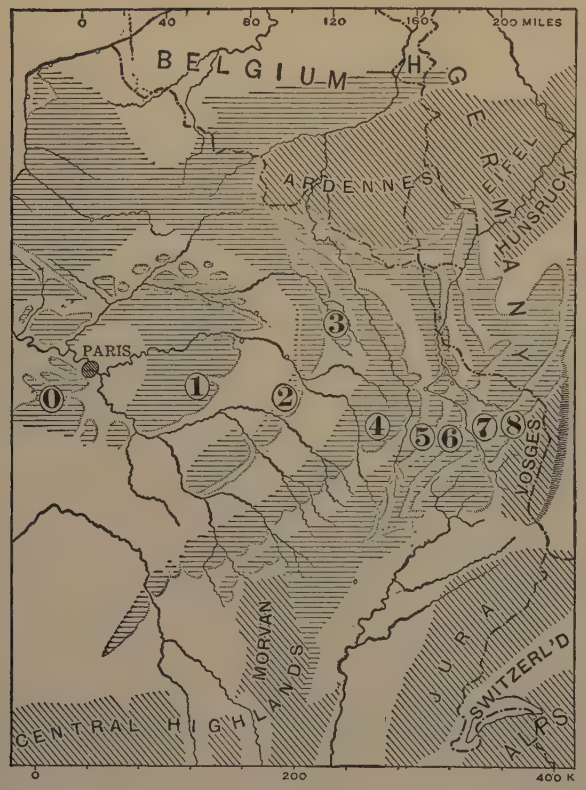


FIG. 230.—Physiographic features of northeastern France, after W. M. Davis. This is essentially a physiographic map rather than a diagram. Such a map, however, can readily be modified so as to have block form if desired, and so that the relief resembles a bird's-eye view. (From W. M. Davis, by permission of Harvard University Press.)

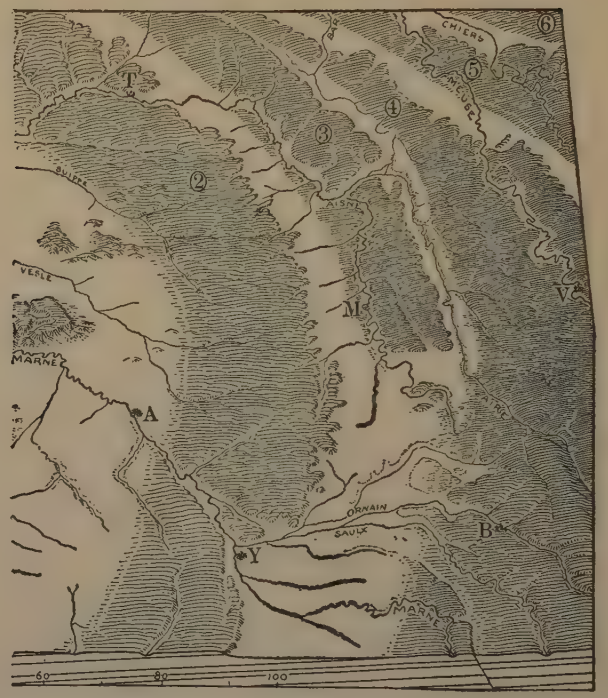


FIG. 231.—The cuestas northeast of Paris. Unlike the preceding figure the structure of the region is shown in the front part of the drawing. Moreover, the effect of this drawing is that of a bird's-eye view. *V*, Verdun; *M*, Ste. Menehould; *B*, Bar-le-Duc; *A*, Chalons. (From W. M. Davis, by permission of Harvard University Press.)

EXERCISES

BASED UPON THE ILLUSTRATIONS IN PART III

Exercise 1. Transform Fig. 230 into a drawing similar to Fig. 231.

Exercise 2. Transform Fig. 231 into a diagrammatic map like Fig. 230.

Note.—An infinite number of exercises can be devised which would make use of the principles demonstrated in this chapter. It is suggested, however, that the student attempt a fair-sized piece of work for himself. While he may feel guided by some of the suggestions in this book, it is almost imperative that he work out a method and technique of his own.

Part IV

LANDSCAPE SKETCHING

131. Introduction.—To the geologist and geographer the ability to prepare a simple sketch in the field or from a photograph must always be a decided asset. A good photograph made under suitable conditions has many things to commend it. Sometimes it approximates very closely to a view of the country itself. On the other hand, photographs have their disadvantages. They always involve expense and a certain inconvenience in the handling of films or plates, packing a camera, and the ultimate finishing of the material. They sometimes befog rather than clarify the situation. They usually lack the simple, direct appeal which a sketch carries with it, because, unlike sketches, photographs can not select out of the landscape just those elements which may be deemed significant. They lack, too, the personal touch which the artist brings to his aid and those subtle qualities of technique which add interest and life to what may be otherwise a prosaic matter.

It is with the belief that the attainment of this so-called "artistic ability" is within the reach of many who would profit from it, that this chapter is introduced here. To those who think it worth while to use sketches in their work, either as a record of their field observations or as a device for the embellishment of their reports, whether professional or scholastic, it is suggested that they constantly carry with them a convenient pocket note book of blank paper and a medium to soft pencil, and upon all suitable occasions prepare one- or two-minute sketches of those objects and scenes which they have the opportunity to observe. Even a poor, unfinished sketch is not to be despised as a record of field observations in geology or geography. In fact, most sketches should be left unfinished, with just enough detail suggested here and there to make it possible to complete the drawing in the office in such a way as to meet the requirements of the problem. Since many of the drawings prepared in the field will not later be found suitable for reports, it is easy to see that it would be a waste of effort and time to complete every field sketch on the ground. Usually it is quite unnecessary that the details of sketches be strictly accurate as to location and form, provided a proper selection of details and a correct emphasis be secured.

The average person, not trained in sketching, is overwhelmed by details. His effort should be, first to select from the landscape those critical and important lines which give it its character, that is, to lay out its major elements. Then after that has been done, is the time to put in some details, not too accurately, but in such a way as to explain better the larger features. Thus, in Fig. 232, there is given at the top a completed landscape sketch, followed by four drawings

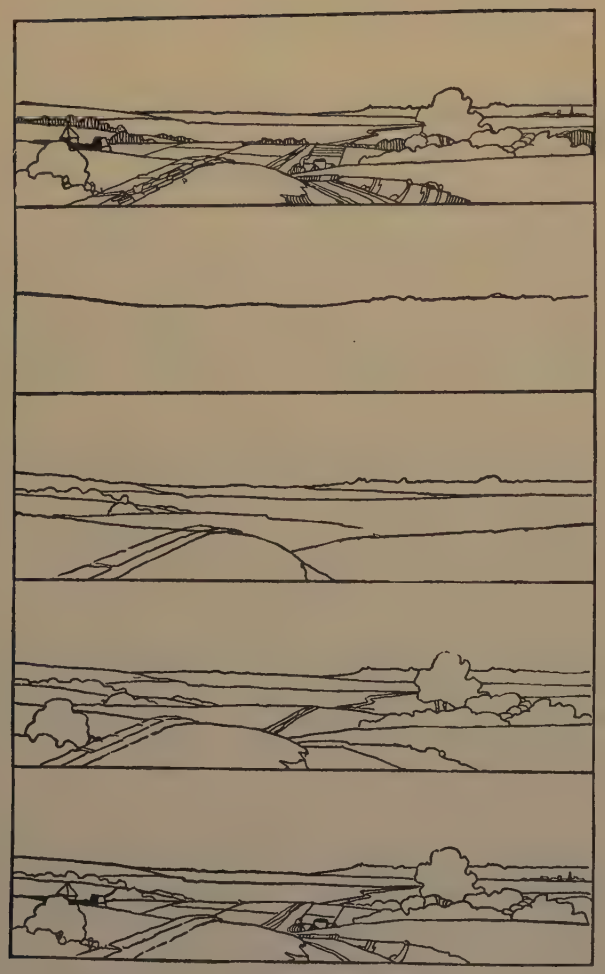


FIG. 232.—Series of sketches showing several stages in drawing a landscape or copying a picture. At the top is the landscape to be copied. The first step is the drawing of the horizon, followed by the drawing of the nearer hills and the major elements in the scene such as conspicuous fences, hedges or roads. Then comes the addition of details, the outlines of trees and woodlands, and then, as in the last sketch, houses and fields are added. The final step, as in the top sketch, involves the simple shading of woodlands and slopes. (From Grieves, Military Sketching and Map Reading, by permission.)

which represent four stages in its preparation. First, the horizon is drawn; then, the hill crests or other major lines of importance. This is followed by the gradual addition of details, such as trees, fields, woodlands, and houses. In some cases it may be necessary to erase parts of lines already made where nearer objects interrupt or obscure them.

The physiographer or geographer, portraying a wild mountain region, concerns himself with the forests only to show the general aspect and character of the country, and not to picture the actual shape of the trees on a particular mountain side. So, in a region of subdued relief the shape of each particular farm or hill is usually not at all necessary, so long as the general nature of the country is suggested and the utilization of the land is shown.

132. The sketching screen.—The sketching screen is a device to assist the beginner to determine on his drawing the positions of the chief elements of the landscape before him. "It [1] consists of a rectangular frame, as shown in Fig. 233, fastened to one end of a horizontal bar, the entire apparatus being mounted on a tripod. A series of vertical and horizontal cords divides the opening in the frame into rectangles. When this apparatus is set up, as illustrated in the figure, and the observer looks through the screen, the vertical and horizontal cords will divide the portion of the landscape, viewed through the frame, into a series of rectangles. The extent of country covered by each rectangle will, of course, vary with the distance of the observer's eye from the screen. For this

[1] Finch: "Topographic Maps and Sketch Mapping."

reason a peep sight is placed in a fixed position at the other end of the bar and opposite the center of the screen.

"In using the sketching screen a sheet of paper is ruled with vertical and horizontal lines just like the lines in the screen. The process of making a sketch from the landscape thus reduces practically to a problem of transferring the lines of the landscape to the paper, rectangle by rectangle, by a process similar to that used in the enlargement of maps by squares. Thus seen through the screen, a house is noted as

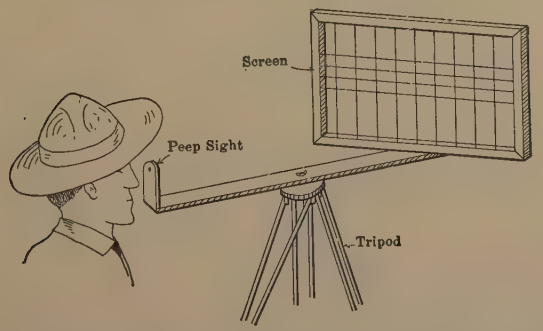


FIG. 233.—The sketching screen. Its use is fully explained under Section 132 of the text. (From Finch's "Topographic Maps and Sketch Mapping," by permission of John Wiley & Sons.)

being in the second rectangle from the left and third from the top and it is then drawn in its proper position in this rectangle on the ruled paper. It is of course unnecessary to transfer every detail from the landscape to the pad in this way. The main points in the landscape are located with the screen and the remaining details are drawn by eye, using these points as guides.

"The process of making a landscape sketch with the aid of the sketching screen is very simple and easily understood. The difficult part of the work is not in drawing delineations for some simple isolated objects such as houses, trees, etc., in their proper position on the paper, but in 'seeing' the lines of the landscape which are needed to represent the ground form properly in the drawing. It is best to start by locating say four or five of the most prominent objects as main guide points and then drawing the sky line and working forward, drawing only the ridge lines first and leaving out all trees and woods. The roads should next be drawn, then the fences, etc. Bear in mind that the effect of distance and form in the relief in the sketch is obtained almost entirely by drawing these objects curving over the hills and valleys as they appear in nature, with careful attention to their perspective. Be careful also to take full advantage of the weight of lines used to bring out the effect of distance.

"The next step in finishing the sketch should be the woods, which must be drawn with simple outline. Distant woods can be shown by a single line indicating roughly the outline of the tree tops; woods nearer the observer are indicated by rough outlines of the most prominent trees. Woods should never be drawn so as to cover up other details that can be clearly seen by the observer.

"In finishing a sketch of this kind remember that, while it is called a sketch, this does not mean that the lines of the drawing can be made carelessly or too freely. Such a sketch is essentially a map drawn in a vertical plane, and the same care must be used in drawing the lines of this sketch as is exercised in drawing the usual conventional signs or in doing freehand lettering. Use a slow uniform motion of the pencil which will give a sharp, definite line, and omit all shading or other lines which have no definite purpose or indication in the sketch."

Figure 234 shows a completed sketch, the ruled lines corresponding with the pattern on the sketching screen. A slightly different form of screen is shown in Fig. 235. The peep hole is replaced by a notched upright stick which keeps the observer's eye at the proper distance. In Fig. 236, the completed sketch is shown.

FIG. 234.—A landscape sketch drawn with the aid of the sketching screen shown in the preceding figure. (From Finch's "Topographic Maps and Sketch Mapping," by permission of John Wiley & Sons.)

Another expedient to determine the relative position of distant objects and their size is that of using a rule or lead pencil, held at a uniform distance from the eye. When the pencil is so used, the thumb serves as a sliding indicator. The use of the rule and pencil in this way is shown in Fig. 237.

133. The sketch pad.—"The [2] sketching screen, while accurate and very useful to the beginner, is clumsy and cannot be easily carried in the field. For this reason it is not used by the experienced sketcher. The horizontal and ver-

[2] Finch: "Topographic Maps and Sketch Mapping."

tical lines on the sketch pad, with the aid of a piece of string, can be made to serve the same purpose.

"Figure 238 shows a page of a sketch pad in reduced size. The actual pad consists of a stiff cardboard back, $6\frac{1}{2}$ by 9 inches in size, to which a number of printed forms shown in

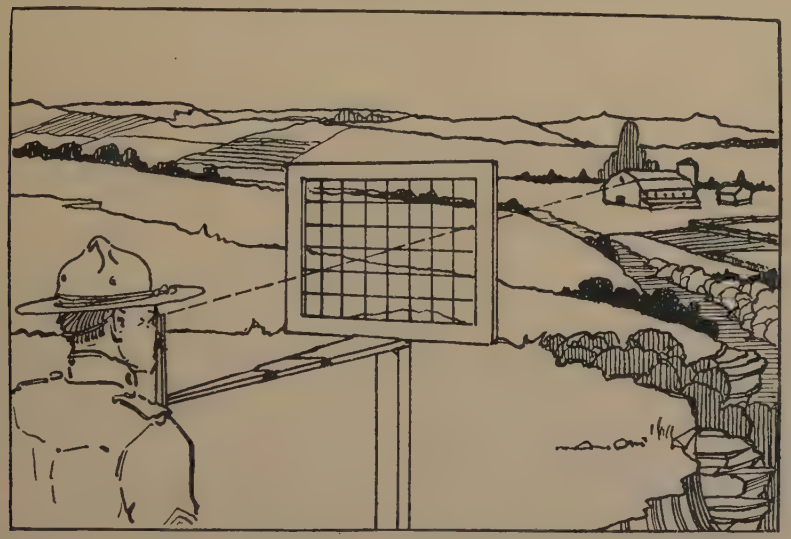


FIG. 235.—A form of sketching screen differing slightly from the one shown in Fig. 233. (From Grieves, by permission.)

the figure are fastened. The vertical lines on these forms are one inch apart and the horizontal lines one-half inch.

"A piece of string is fastened to the bottom of the pad. and a knot is put in the string at twenty inches from the pad. In using the pad the end of the string is held in the teeth and the pad in the left hand. Thus the string fixes the distance from the observer's eye to the pad, just as the peep sight does with the sketching screen, and the lines on the pad itself take the place of the frame and strings of the screen. The pad, not being transparent, has to be used in a manner slightly different from that used with the screen. That is, we locate points of the landscape in their proper position on the

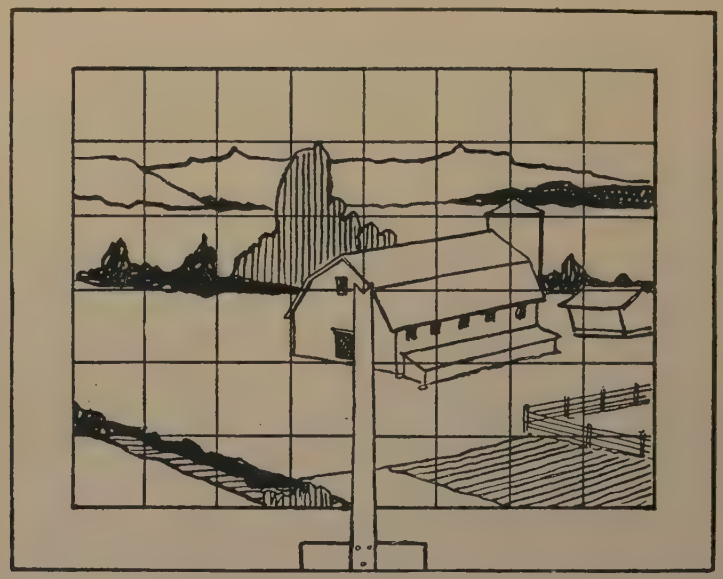


FIG. 236.—Landscape sketch drawn with the aid of the sketching screen shown in Fig. 235. (From Grieves, by permission.)

pad not by sighting through it, but by noting their positions along the top and side edges of the pad. The procedure is as follows:

"1. The sketcher selects some prominent point on the landscape as a 'reference point' and locates this point at the intersection of one of the vertical with one of the horizontal lines of the pad.

"2. Other prominent, or guide points, for the sketch are first located on or between the proper vertical lines, to the

FIG. 237.—The use of rule or pencil in measuring for landscape sketches. (From Grieves, by permission.)

right or left of the reference point, by using the top edge of the pad as a scale. Thus with the pad held vertically, twenty inches from the eye, and with the selected *vertical* line directly under the reference point on the landscape, we note, by sighting along the upper edge of the pad, that some prom-

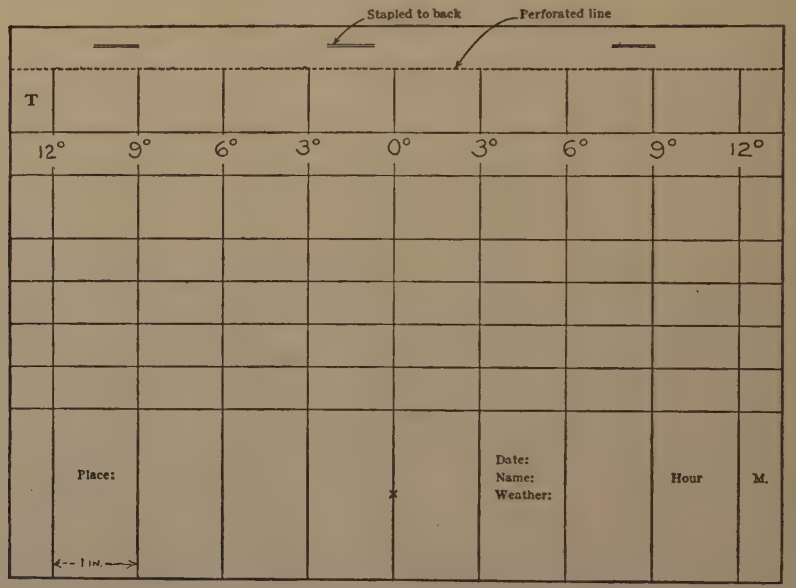


FIG. 238.—Page from sketch pad. Actual size $6\frac{1}{2} \times 9$ inches. (Slightly modified from Finch by permission.)

inent object is two and one-half vertical spaces to the right of the reference point. Now, holding the proper *horizontal* line even with the reference point and sighting down the vertical edge of the pad, we see that this same object is, say, one horizontal space below the level of the reference point. The intersection of two lines, the first a vertical line two and one-half spaces to the right of the reference vertical and the

other the horizontal line below the reference point, determines the location of the object on the pad.

"3. Having located in this manner on the pad a number of the main points of the landscape, the observer proceeds to sketch in the landscape as previously described.

"In many cases it is desirable, in order to get more space and hence a clearer sketch, to exaggerate the vertical scale of the drawing. For example we may note the number of horizontal spaces an object is above or below the reference point and then double this value when plotting its location on the pad. This procedure is similar to that followed in making profiles. The effect on the sketch is to make it appear that the observer had made the sketch from a much higher elevation than he actually occupied."

134. Mapping from landscape sketches.—The geographer or geologist, not especially equipped for mapping, and having no available or suitable map, may make several sketches or photographs which will serve him later in the preparation of a map or block diagram of the region. A very simple demonstration of the entire procedure is shown in Fig. 239. The three sketches were made from widely separated points, *A*, *B*, and *C*. In each case the distance of the sketch pad from the eye of the observer is known, as well as the direction toward which the observer faced. In Fig. 239 the distance of the sketch pad from the observer is the same for all of the sketches, but it is not necessary that this should be so. The position of the three points, *A*, *B*, and *C* must be definitely, or at least approximately known before a map can be made. Plot the points *A*, *B*, and *C*, according to the scale of map desired, and proceed as follows: Drop vertical lines on each sketch from the critical objects to the bottom of the sketch. Lay each sketch down, as shown in Fig. 239, with its base a distance from its point of observation, *A*, *B*, or *C*, equal to the distance the sketch pad was held from the observer's eye. Then draw pencil lines from the points *A*, *B*, and *C* to the points along the bottom edge of the several sketches directly below the important objects in the

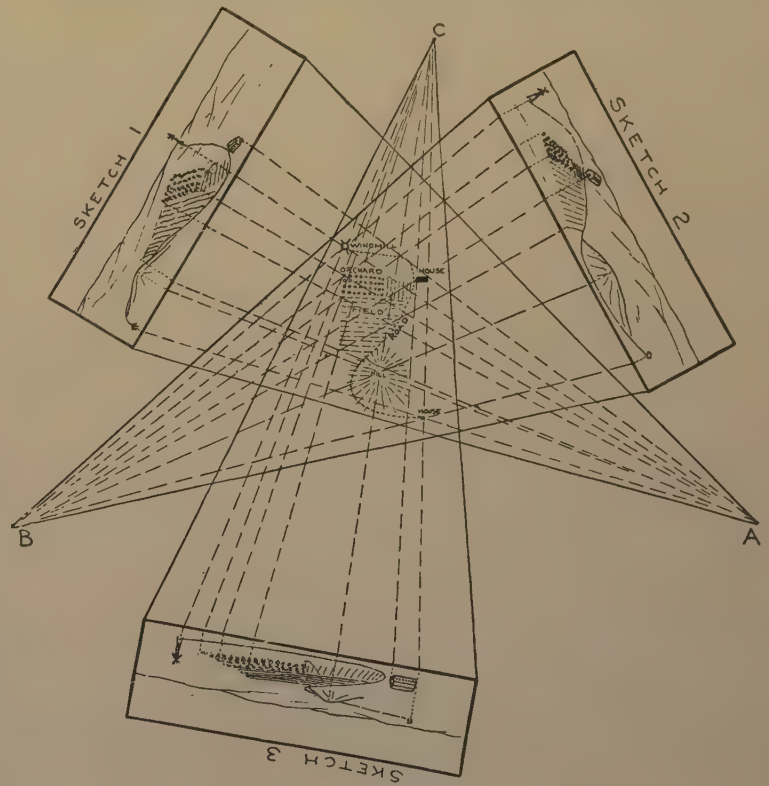


FIG. 239.—Preparation of map from data recorded on sketches. Two sketches only are necessary but three or more sketches provide greater accuracy. This method is explained under Section 134 of the text.

sketch. This is clearly shown in Fig. 239. The intersections of these various lines determine on the map the positions of the various objects. For most work two sketches of a given area will suffice, provided the directions of view are almost at right angles, so that intersections of the various lines may

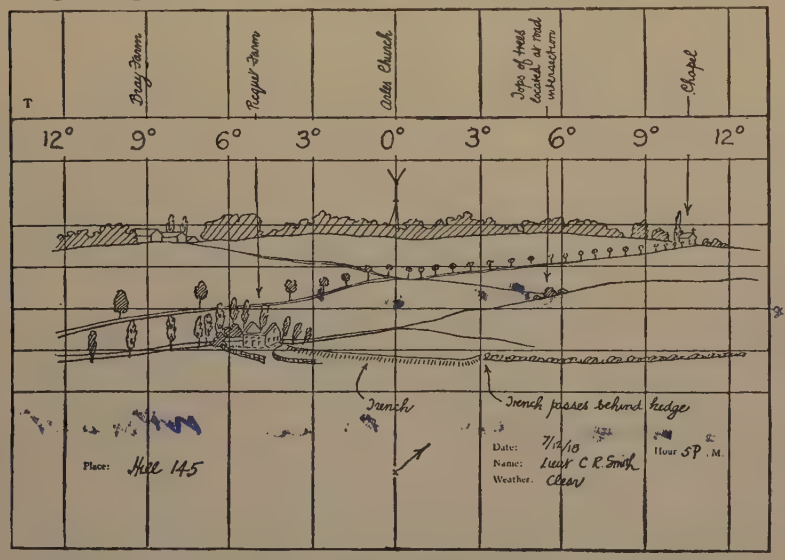


FIG. 240.—Complete landscape sketch prepared on sketch pad held about 20 inches from the eye. The upright rulings are 1 inch apart and consequently represent horizontal angular differences of about 3 degrees. The picture, which is 9 inches long, subtends an arc of about 24 degrees. (Modified from Finch, by permission.)

be more or less accurately established. In Fig. 239, however, the position of each critical point is determined by the intersection of three lines.

135. Ruling of sketch pad to facilitate angular horizontal measurements between objects.—It will be found that if the sketch pad is held about 20 inches from the eye of the observer (actually a little less, nearly 19 inches), one inch horizontally on the sketch will represent a horizontal angle of 3 degrees, as shown in Fig. 240. A sketch 10 inches long, therefore, would cover an arc of about 30 degrees. If the sketch pad is ruled, therefore, with vertical lines one inch apart, it is easy to estimate within a degree the angular distance between distant objects. Then instead of following the procedure demonstrated in Fig. 239, which requires a rather large sheet of paper (more than 20 inches long if the picture plane is held that far from the eye), one may plot the actual angles between objects with a protractor placed at the points A, B, and C successively. Thus in Fig. 240 one may read the angular distance between the various objects. For example, the chapel at the right is about $10\frac{1}{2}$ degrees from the middle of the picture. The house in the foreground is about 5 degrees to the left of the center. The *mil system*, used in measuring angles in military work, is an adaptation of this method. (See Finch's "Topographic Maps and Sketch Mapping.")

136. Delineations.—After the main elements of the topography or landscape have been blocked out, the details are added. In simple sketches it is usually more advisable to represent trees, buildings, fields, and other details in a conventional way, rather than try to picture the actual object before one's eye. This is necessary because time does not permit of much accuracy, nor is it especially desirable for most purposes. These simple conventional forms or delineations should be drawn with as few strokes as possible, and little effort at real artistic effect should be made. The student who finds himself awkward with a pencil will do well to practice some simple pencil strokes, such as those shown at the top of Fig. 241. Try these and other similar designs

FIG. 241.—Delineations. Simple strokes and symbols used in landscape sketching. (From Grieves, by permission.)

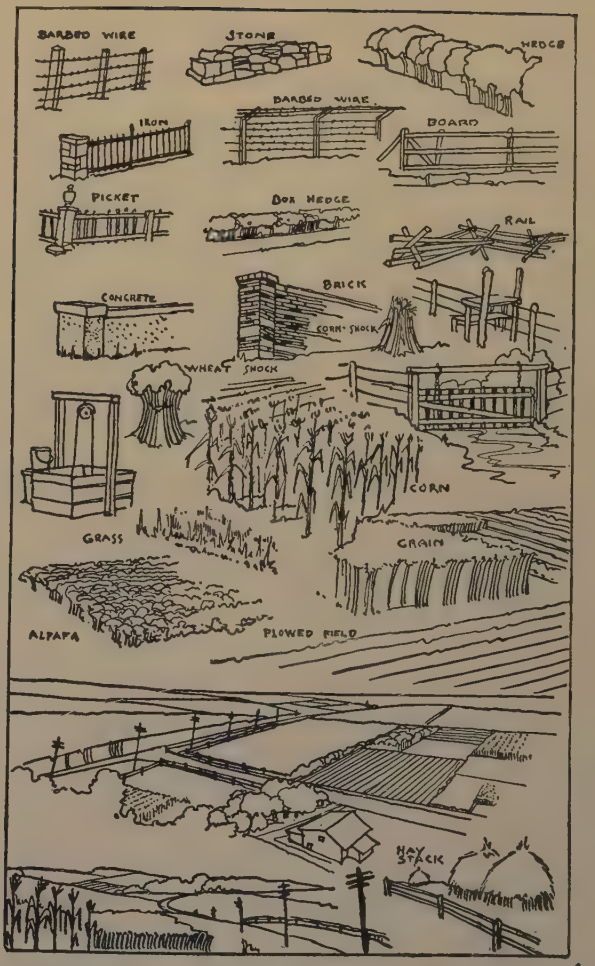


FIG. 242.—Delineations and landscape sketches. (From Grieves, by permission.)

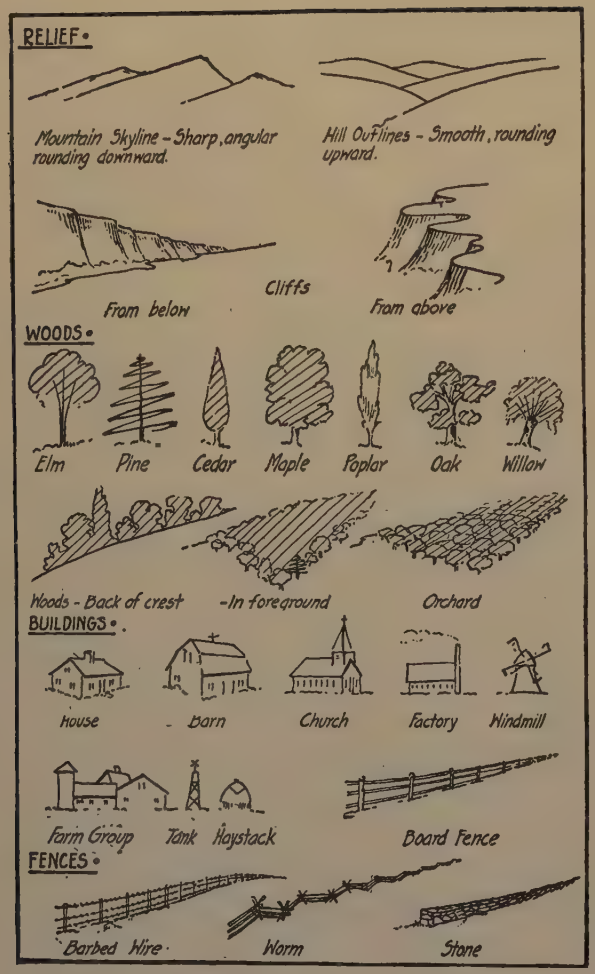


FIG. 243.—Delineations. (From Finch, by permission.)

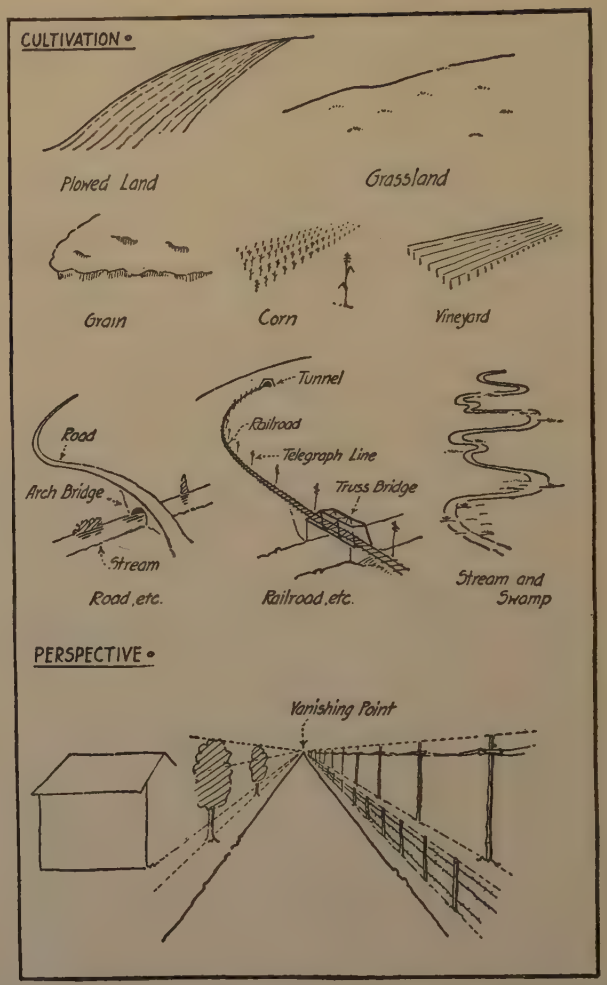


FIG. 244.—Delineations and perspective. (From Finch, by permission.)

and strokes over and over again with a medium to soft pencil, using a note book with paper that is not too smooth. In this way a facility in handling the pencil is readily acquired, so that when actual sketching is attempted the pencil easily goes where it is supposed to go. Follow up these simple

FIG. 245.—The use of vanishing points in sketching buildings. In the upper half of the drawing one vanishing point is used. Some of the buildings are entirely above the eye, some are entirely below, others are partly above and partly below. In the lower half of the drawing two vanishing points are used. Several types of buildings are shown in both perspective and simple elevation.

strokes with sketches of buildings in various positions, groups of buildings both near and at a distance, trees of different kinds, single and in groups, near and far away. These are all shown in Fig. 241. Other symbols are given in Fig. 242, including various kinds of fences and crops, and also a little sketch which combines a number of the delineations into an actual scene. Figures 243 and 244 suggest other simple devices, all of which may be studied with profit. In Fig. 245 the use of perspective methods in the drawing of buildings is more

FIG. 246.—Kittatinny Mountain and Delaware Water Gap, looking across Kittatinny Valley from the Highlands of New Jersey. Note the extremely simple profile of the distant ridge, no slope lines, nor trees, nor shading of any kind. In the foreground trees are suggested, and in the intermediate distance there is a very slight attempt at shading, but throughout the sketch the paucity of lines is notable. (From W. M. Davis, by permission of Ginn & Co.)

FIG. 247.—Appalachian ridges near Mauch Chunk, Pennsylvania. Simple profiles with a perspective effect obtained by the different size of the tree symbols. Note that the distant profiles are not full lines but are made up of very short vertical strokes which suggest the forest. (From W. M. Davis, by permission of Ginn & Co.)

definitely shown, the adoption of one or two vanishing points helping materially in obtaining the correct effect.

137. Development of technique.—As in any line of endeavor, the most rapid progress is made by studying the

FIG. 248.—Gap of upper Juniata River in Black Log Mountain, an Appalachian ridge in central Pennsylvania. Simple profiles made up of short vertical lines to represent the forest cover. Buildings in perspective are shown very simply and give scale to the view. The railroad and river give a pleasing effect of distance. (From W. M. Davis, by permission of Ginn & Co.)

FIG. 249.—Gap in Shade Mountain, central Pennsylvania. Woods, fields, buildings, fences and roads, all suggested by the simplest possible means. (From W. M. Davis, by permission of Ginn & Co.)

FIG. 250.—Pennsylvania ridges on the upper Susquehanna River. Simple distant profiles with bolder strokes in the foreground. (From W. M. Davis, by permission of Ginn & Co.)

work of others who have attained success. The two outstanding figures in American physiographic sketching are undoubtedly W. H. Holmes, the artist geologist who accompanied the early Hayden Surveys in the Rocky Mountain

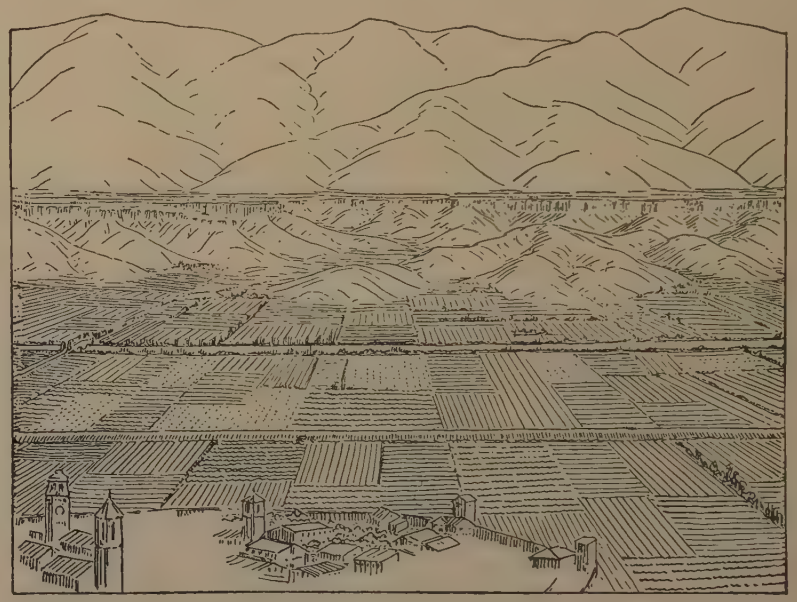


FIG. 251.—The Val d'Arno in northern Italy. The Apennines in the distance shown by simple outlines. The lower spurs stick out from beneath a high terrace which is preserved on their upper slopes. This is all in strong contrast with the darker tone of the cultivated fields. Note the use of a single vanishing point in sketching the fields. Usually high or distant objects are shown in few and simple strokes so that a light or airy effect is produced. Nearby objects and lowlands are represented by heavier or more numerous strokes. (From W. M. Davis.)

and Colorado Plateau regions, and W. M. Davis, dean of American geographers, whose splendid sketches and diagrams adorn so many publications. A few examples of the work of

these two men are included in this book, but other equally good material from their pens may be found elsewhere in numerous reports, some of which are cited in the reference list at the end of this volume.

Fig. 252.—The Rocky Mountain upland south of Denver. The skyline profile is the most important part of these views and is drawn as a definite line. The foreground details are less important and hence are shown in a rather sketchy manner. The use of tree symbols to gain perspective is worthy of note. (From W. M. Davis.)

Figures 246, 247, 248, 249, and 250, by W. M. Davis, are very simple but effective representations of parts of the Appalachian ridges of Pennsylvania and New Jersey. Comments on each of these pictures are given in the legends accompanying them. Figure 251, also by W. M. Davis, is a splendid example of striking effect gained by the simplest possible means.

Figure 252 may suggest a means of handling the scenery of a wild, rugged upland where the only real striking element

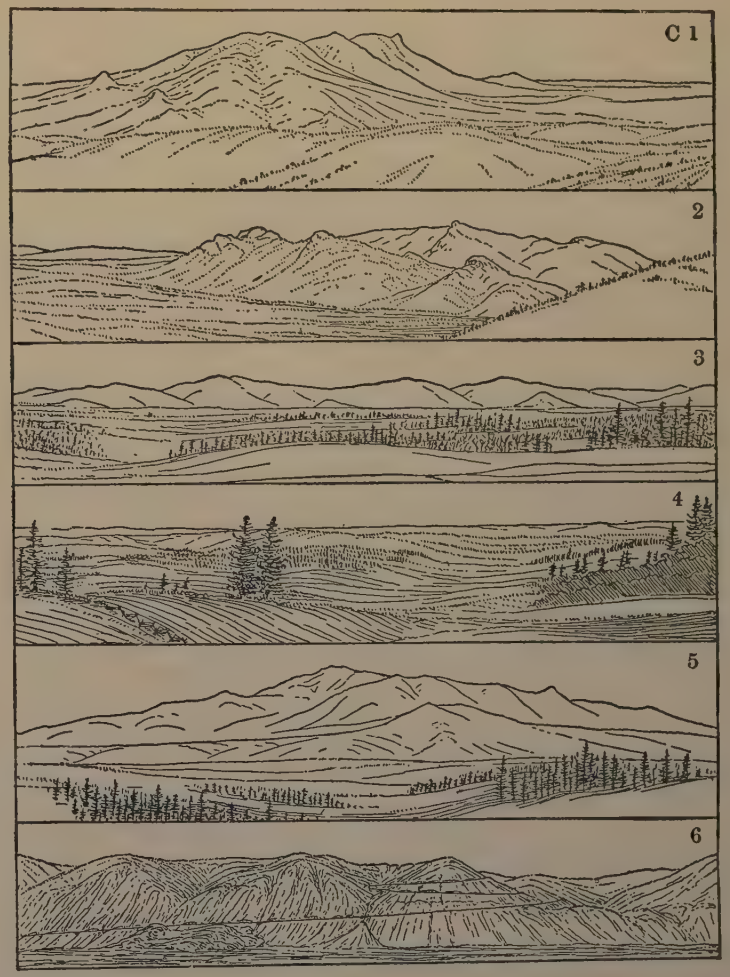


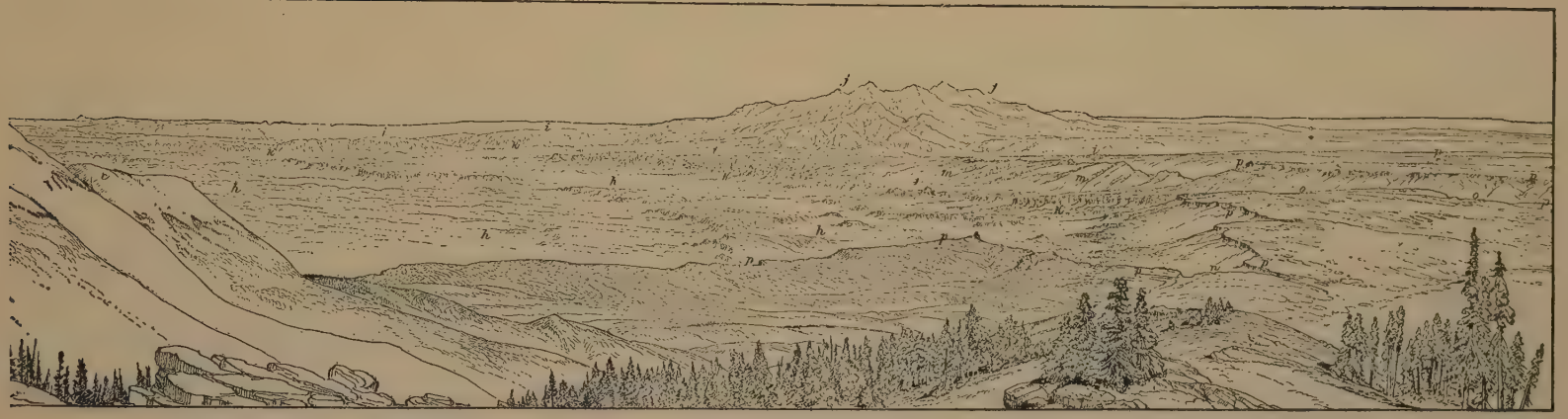
Fig. 253.—Sketches of the Colorado Rockies. (From W. M. Davis.)

FIG. 254.—Panorama from Abajo Peak, looking north and west. (Drawn by

in the topography is the distant level skyline. The exact features in the foreground are of almost no importance and are represented in a less decisive fashion. In Fig. 253 a number of different scenes are presented, showing a technique which is well worthy of emulation.

Examples of work by W. H. Holmes are to be found in most of the Hayden Survey Reports, especially those for 1875 and 1876. The inimitable drawings of the Grand Canyon in the Atlas accompanying Dutton's report of that region (U. S. Geological Survey, Monograph No. 2) represent the high-water mark in landscape sketching. Figure 254 taken from Hayden's report for 1876 is one of the best examples of a panorama covering a wide arc of view. As published, this panorama is almost 38 inches long. The simplicity of the lines and occasional coarseness of stroke adopted by Holmes make landscape sketching look easy, and it is only a careful study and appreciation of his work that reveals him as a past-master in the art. His handling of vegetation is noteworthy and is not likely to be approached by the amateur. The use of vegetation, especially trees, to gain a perspective effect, has already been commented upon. Holmes makes use of this device on mountain slopes that are forested. In plateau districts, devoid of vegetation, however, he resorts to figures of men and animals instead, as in Fig. 255. Figure 256 gives two other examples of Holmes' work in which excellent and satisfactory effects are gained by simple means.

138. Sketching from photographs and in the field.—The artist should first analyze his subject and determine its major elements. He should study it critically with an eye to its perspective. If the subject, as in many cases already discussed, consists of almost nothing but a series of hill or ridge profiles, he gains perspective by drawing the most distant line, usually the horizon, first. This is drawn very



W. H. Holmes. From Hayden's Report for 1876 on Colorado and adjacent territory.)

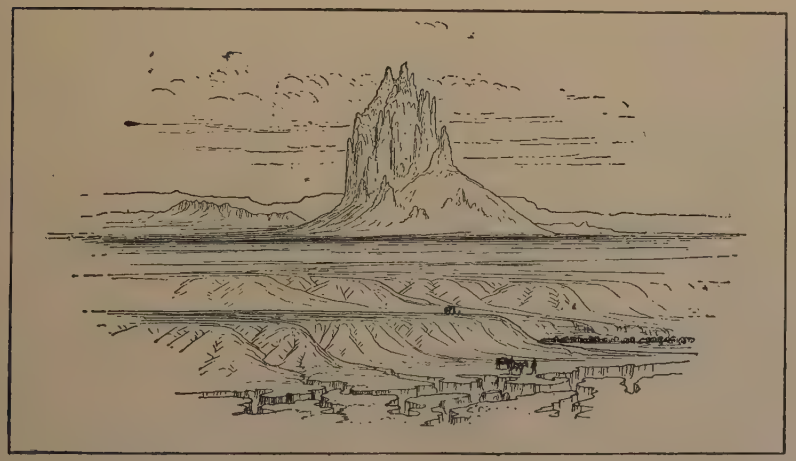


Fig. 255.—The Needles, a volcanic neck south of San Juan, New Mexico. These pinnacles rise to a height of 1680 feet above the level plain around them. This imposing height is better realized from the sketch because of the figures in the intermediate foreground. Note the varying size of the figures, depending upon distance. In this sketch another device to give the effect of distance consists in the closer spacing of the horizontal lines in the distant part of the plateau. (Sketch by W. H. Holmes, from Hayden's Report on Colorado and adjacent territories.)

lightly. Then he works forward with stronger and bolder strokes until he reaches the immediate foreground. The details are all put in afterward. Figures 257 and 258 may suggest this simple treatment of a photograph. The view in Fig. 257 presents a number of details which are unnecessary. The most important lines are the ridge profiles. In Fig. 258 these have been expressed with varying degrees of boldness, depending upon distance. The vegetation and river bank in the foreground are represented by coarse and even crude strokes, the distant ridge much more delicately.

Figures 259 and 260 are simple sketches made from photographs. These sketches were prepared very rapidly

Fig. 256.—Sketches by W. H. Holmes from Hayden's Report on Colorado and adjacent territories

and easily by using a grade of rather tough oiled tracing paper which is fairly transparent. The photographs were traced directly in ink with a rather fine business pen or crow-

Fig. 257.—The Susquehanna Water Gap at Rockville, Pennsylvania, near Harrisburg.

quill pen. The important thing is to leave out unessential details.

In landscape sketching, however, the features should be analyzed and wherever possible should be considered

Fig. 258.—Pen and ink sketch made from photograph shown in preceding figure. The distant features are shown lightly, the nearer ones boldly. Unessential details are eliminated.

as geometrical solids. The blocking in of these solid masses, as already discussed in the early chapters of this book, engages the artist's attention first. He calls to his aid a few rules of perspective, introduces vanishing points

where desirable, and transforms the scene before him into a combination of geometrical forms. Thus, the butte in Fig.

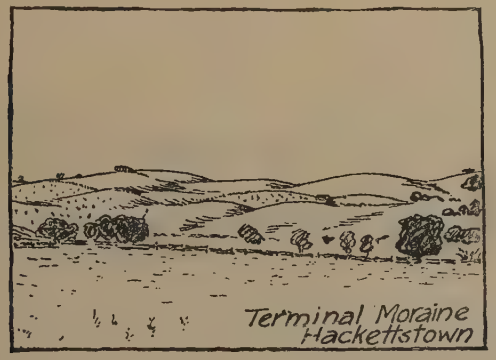


FIG. 259.—Pen and ink sketch showing general character of terminal moraine near Hackettstown, New Jersey, from a photograph.

FIG. 261.—Butte on the Great Plains near Cambria, Wyoming. (Photo. by Darton, U. S. Geological Survey, No. 63.)

261 may be considered as a rectangular block placed above the observer's point of view. The use of two vanishing points

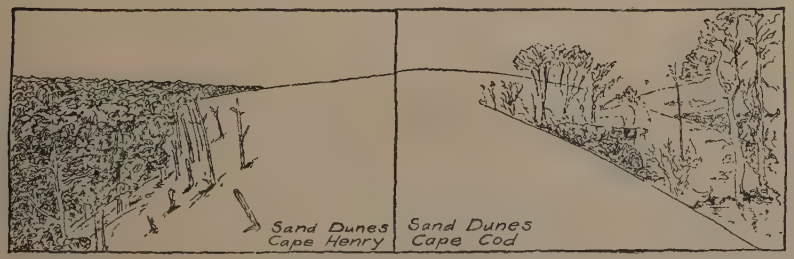


FIG. 260.—Pen and ink sketches made from photographs of large migrating sand dunes on Cape Henry and Cape Cod.

in drawing this butte is demonstrated in Fig. 262. After the essential form is blocked out in this way, details may be

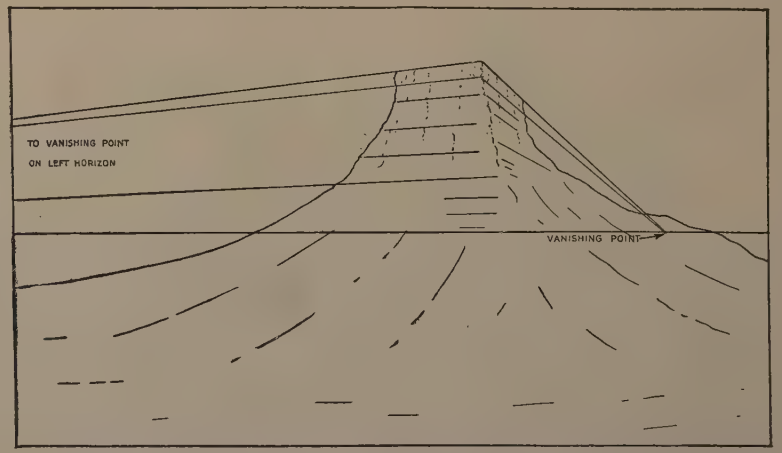


FIG. 262.—Use of vanishing points and perspective lines in sketching the butte shown in the preceding figure.

added. Or take the picture of Taghanic Falls, near Ithaca, N. Y., shown in Fig. 263. The use of a horizon with vanishing points and perspective lines is illustrated in Fig. 264. In this case the so-called "horizon" is not horizontal, because the plane of the formations is tilted. In Fig. 265, and its corresponding outline sketch, Fig. 266, the view has to do

Fig. 263.—Taghanic Falls, near Ithaca, New York. (Photo. by Gilbert, U. S. Geological Survey, No. 1963.)

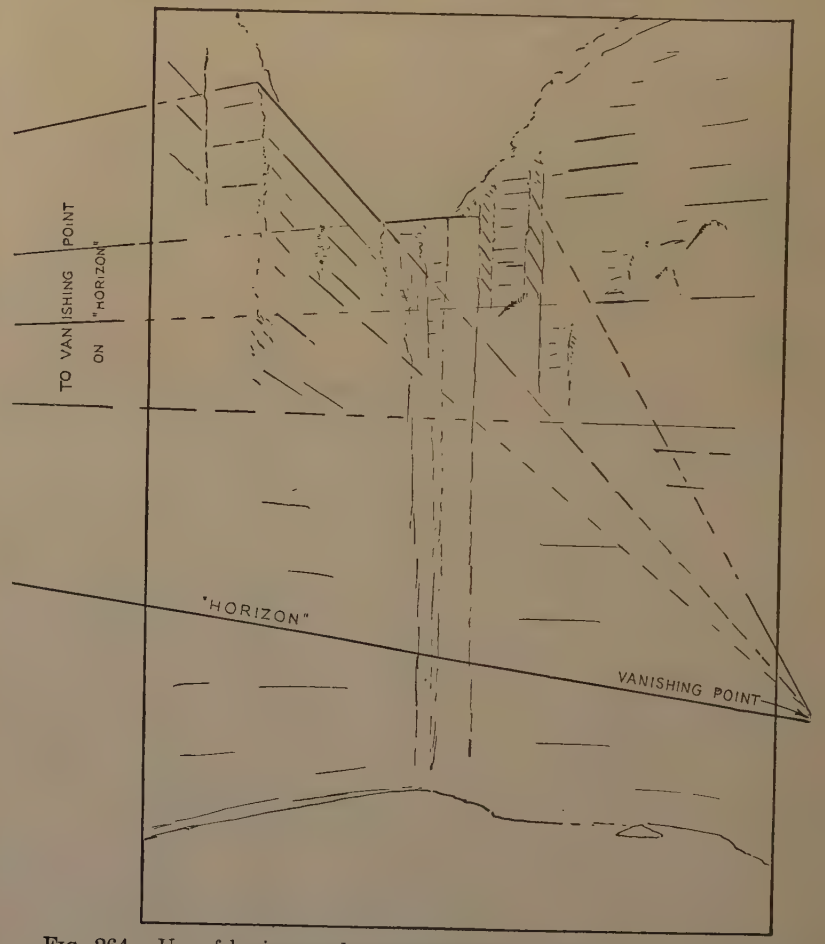


Fig. 264.—Use of horizon and vanishing points in sketching Taghanic Falls, shown in the preceding figure.

FIG. 265.

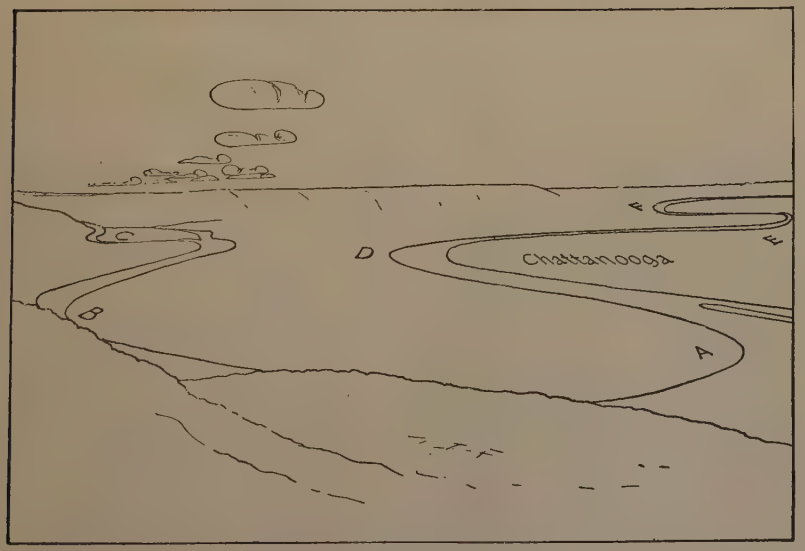


FIG. 266

FIG. 265.—Moccasin Bend on the Tennessee River, looking south from Lookout Point, near Chattanooga.

FIG. 266.—Outline sketch of the photograph shown in the preceding figure, indicating the major elements. The letters *A*, *B*, *C*, *D*, *E*, and *F* refer to points similarly marked on the map, Fig. 267. The greater width of the river at the points *A*, *B*, *D*, and *F* contrasts with its apparent narrowness between these points. Reference to the map, however, shows that the river has an almost uniform width everywhere. Another device for introducing distance into a sketch is the use of clouds. The clouds far away seem closer together than the nearer ones. Compare with the photograph, Fig. 265.

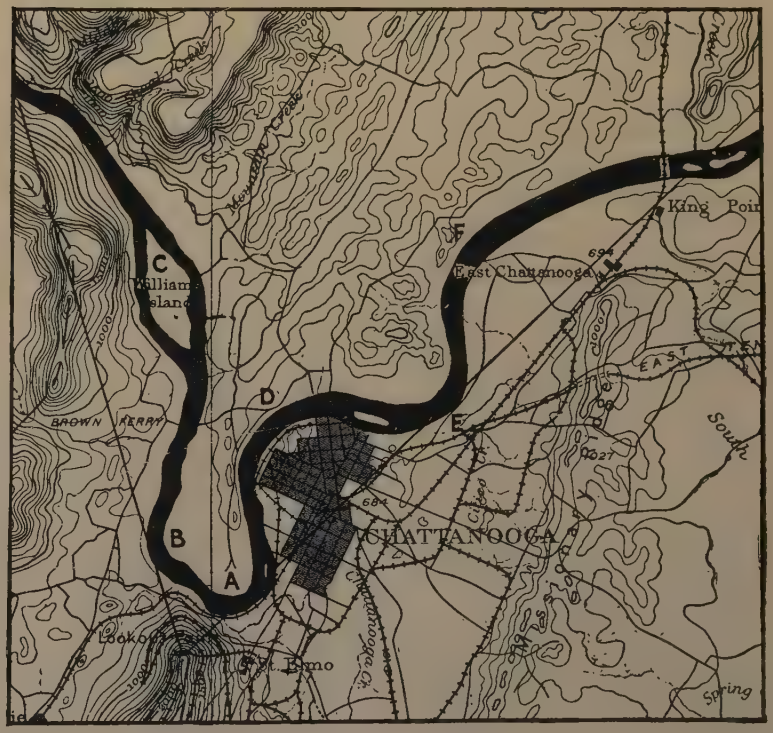


FIG. 267.—Map of Moccasin Bend, shown in Fig. 265. The point from which the picture was taken is named Lookout Point. The two lines drawn from this point enclose the angle of view encompassed in Fig. 265. The points *A*, *B*, *C*, *D*, *E*, and *F* correspond with the points similarly lettered in Fig. 266.

with a broad plain, and the important lines in the sketch are those which represent the two sides of the Tennessee River. The horizon in the distance offers no problem. The effect of foreshortening, both in the meander curves and in the width of the stream, is strikingly brought out if the picture is compared with a map of the same region, shown in Fig. 267. The legends to the last three figures explain the matter more fully.

Three other photographs are given here as offering suitable exercise material in the sketching of landscapes. Figure 268 shows two small gulches with talus cones, or torrential fans, at their ends. In sketching this scene, the first line to draw is the crest of the ridge in the intermediate distance, then the skyline of the mountains, followed by some bolder strokes in the foreground. Try to get the effect of distance by varying the strength of line and the size of trees. In drawing the gulches and torrential fans, consider them as geometrical cones, inverted and upright respectively.

The drawing of Fig. 269 will present greater difficulty than that of Fig. 268. Lay out the mountain mass as a great dome, and then modify it by introducing cirques. The peaks rising above the cirques and the ridges extending below them may then readily be drawn in. Even if not very accurately placed, they will nevertheless look all right if they have the proper relation with each other and are properly drawn. Note the perspective effect in the streets and houses of Silverton. Determine the horizon and the position of the single vanishing point.

In Fig. 270 the simple outlines of the main features are easily drawn. The broad valley floor offers good opportunities to get the proper distance effects by means of houses, fences, trees, and fields. The boldness of the foreground is in contrast with the delicate shades of the distant peak.

FIG. 268.—Gulches with torrential fans. Silverton district, San Juan Mountains of southern Colorado. (Photo. by Howe, U. S. Geological Survey, No. 103).

FIG. 269.—Silverton, Colorado. Sultan Mountain beyond, with glacial cirques. (Photo. by Ransome, U. S. Geological Survey, No. 32.)

FIG. 270.—Mount Shasta, California, with cinder cones in the foreground.

139. Blackboard sketches.—The chief difference between a blackboard sketch and a sketch on paper is that one is temporary and the other more or less permanent. This, together with the fact that far less detail is possible when chalk is used as a medium of expression, means that in general blackboard sketches should be hastily prepared, and that

FIG. 271.—Blackboard sketch used to explain the geographic factors in the development of Switzerland. (Modeled after W. M. Davis. See Fig. 167.)

they should be simple in character in order that speed in preparing them may be possible. They should be bold so that they may be seen across the room. If they can be drawn before the eyes of the class, so much the better, but this means all the more that speed is important. If a picture or drawing is to be copied on the blackboard, to be used later for class demonstration, detailed accuracy of form is not especially necessary as long as the general effect is obtained.

Figure 271 shows a blackboard sketch modeled after one of Davis' drawings and used in a class to illustrate some of the geographical factors in the development of Switzerland. Comparison with the original drawing, Fig. 167, will reveal

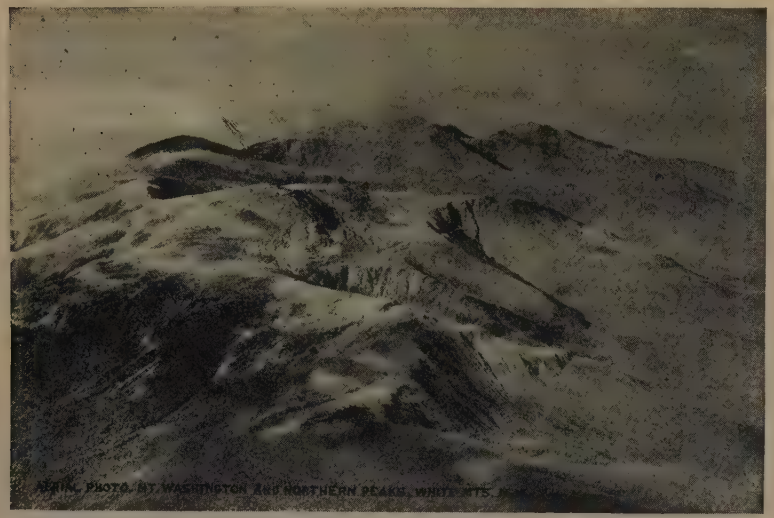


FIG. 272.—The White Mountains of New Hampshire. Viewed from an aeroplane flying over the range south of Mount Washington. The view is toward the Northern Peaks.

the omission of much detail, with the retention of the main ideas. It is worth remarking at this point that usually blackboard drawings look extremely crude when viewed from close by but at a distance the lines melt into each other and the desired effect is gained by the class. A teacher doing blackboard work should therefore familiarize himself with the effect of his drawings at a distance so that he may be willing to put the proper boldness into his work when seen at close range.

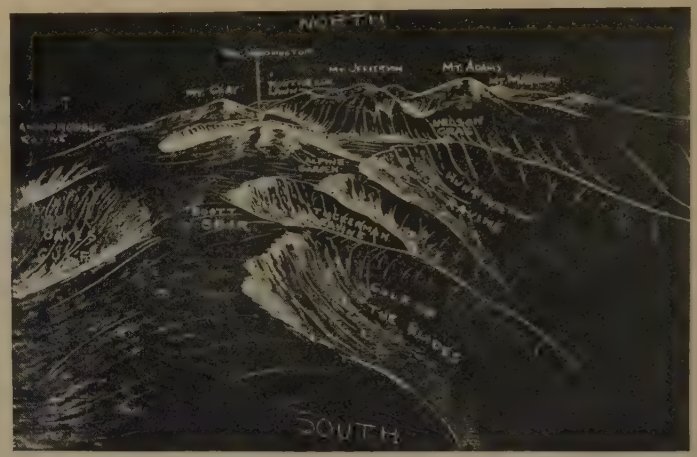


FIG. 273.—Blackboard sketch drawn from Fig. 272, showing the main features of the Presidential Range in the White Mountains, New Hampshire.

Figures 272 and 273 show a photograph and corresponding blackboard sketch of part of the White Mountains. Such a photograph, if used for laboratory study, would not inspire a class. It is too small and too faint. The blackboard sketch puts vigor into the subject and offers a means of explaining the land forms more definitely.

EXERCISES

Based upon the Illustrations in Part IV

Exercise 1. Complete the bottom sketch of Fig. 232 by shading as in the top sketch.

Exercise 2. Prepare a sketching screen, modeled after Fig. 233 or Fig. 235, using an old picture frame or heavy cardboard with threads stretched across at regular intervals. Mount, as shown, with peep sight, and with its aid draw several sketches both indoors and outdoors.

Exercise 3. Prepare page for sketch pad, similar to Fig. 238. Draw the vertical lines one inch apart and the horizontal lines one-half inch apart. Fasten to light drawing board or heavy cardboard. With its aid draw sketches similar to those prepared for Exercise 2. Draw one sketch twice; first as the view appears; second with vertical scale exaggerated, as explained in the last paragraph of Section 133 of the text.

Exercise 4. Prepare sketches of Figs. 268, 269, and 270 in accordance with suggestions given in Section 138 of the text.

Exercise 5. Select two or three points in the open overlooking the same region. Draw a sketch from each station, using sketch pad, prepared according to suggestions given in this chapter. Then make a simple map, using the principles demonstrated in Fig. 239.

Part V

CRYSTAL DRAWING

140. Introduction.—Inasmuch as this chapter will appeal only to students of mineralogy, it will be assumed that the reader has access to such standard books as Dana's "Text-Book of Mineralogy," wherein he may find an explanation of the drawing of crystal figures. A more elaborate discussion by S. L. Penfield, "On Crystal Drawing," will be found in the *American Journal of Science*, vol. 19, pp. 39–75, 1905. An excellent elementary book is "Hints for Crystal Drawing," by Margaret Reeks. Each of these authors describes the usual clinographic projection and the standard position of the axes as they are used for drawing the figures in most text-books on mineralogy.

The purpose of this chapter is to suggest a simple way of sketching out the crystal axes and of drawing the more elementary forms in such a manner that the teacher can sketch these forms rapidly on the blackboard while explaining the forms before the class. It is also believed that these simple hints may appeal to the student of crystal forms, who in his studies wishes to prepare drawings that will aid him in comprehending various crystal faces, without the need of such accurate measurements as the usual methods require.

The first task in drawing a crystal form is the representation of its axes. In all standard works on crystallography the crystals are drawn in what is known as clinographic projection. In this projection the crystal is viewed from a point slightly above the object, but at the same time as if seen from an infinite distance. The crystal is also turned on its vertical axis so that neither one of the other axes runs directly along the line of sight. The position which has been uniformly adopted depends upon certain angles which have convenient trigonometrical functions that aid materially in accurate representation. In the three references already noted this matter is fully explained. For text-book illustrations and for the preparation of crystal drawings for publication, one should unquestionably adhere to these methods because they have been found suitable and are in almost universal acceptance. For less formal work, however, instead of using the clinographic projection it is proposed that greater facility in drawing crystal forms can be secured by using what is sometimes known as cabinet projection.

141. Axes of the isometric, tetragonal, and orthorhombic systems in cabinet projection.—In each of these three right-angled systems, it is suggested that the vertical axis and one of the horizontal axes be drawn at right angles to each other

and with their correct relative lengths. As for the other horizontal axis, this is drawn arbitrarily at an angle of 30 degrees to the horizontal and with a length one-half of what it should be, relatively to the lengths of the other axes. The angle of 30 degrees is proposed because of the convenience in using the 30–60 degree triangle on the drawing board. For freehand and blackboard sketches any angle approxiating 30 degrees will be found satisfactory. If a comparison is now made between crystal forms of different systems drawn in cabinet projection, and corresponding forms drawn by the more painstaking clinographic projection, it will be noted that there are very few radical points of difference.

Figure 274 is arranged so that such a comparison may be made in the isometric system. To one thoroughly familiar with the usual text-book illustrations, the slightly greater width of the forms drawn in cabinet projection may be distasteful, but to the average student this will afford no irritation. In fact, it is believed that the cabinet projection occasionally suggests the true dimensions even better than does the standard clinographic projection. The cube, for instance, in Fig. 274, when drawn in cabinet projection, suggests equidimensional axes even better than does the cube in clinographic projection.

Figure 275 presents similar forms in the tetragonal system. The vertical axis is longer than the other axes in the ratio of $1\frac{1}{2}$ to 1. In the cabinet projection this ratio can actually be measured off, the same scale being adopted for the vertical c axis as for the horizontal a axis. The two a axes remain the same as for the isometric system.

In Fig. 276 the orthorhombic system is shown. The a axis is assumed to be the shortest, with a length one-half that of the b axis. It is, therefore, in the cabinet projection, drawn one-fourth as long, since in this projection the a axis is made one-half of its true length.

It is believed that further study of these figures will commend the cabinet projection to both teacher and student

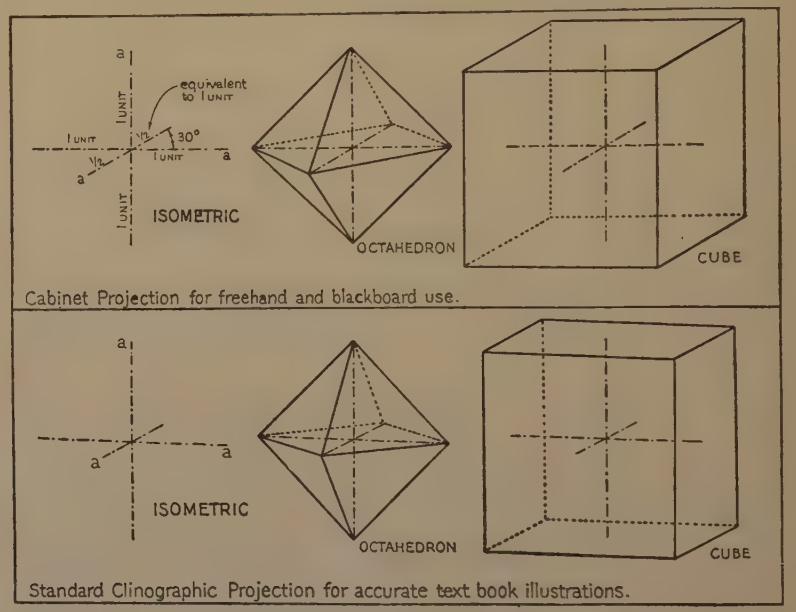


FIG. 274. Isometric axes and crystal forms. Comparison between cabinet and clinographic projections.

because of the convenience and ease with which it may be used.

142. The drawing of crystal faces.—The representation of the various crystal forms in cabinet projection follows exactly the same procedure as in clinographic projection, once the axes have been laid out. Several methods may be employed, as follows:

1. The method of plane intersection.
2. The parallel method, or parallelism.
3. The method of symmetry or repetition.
4. The profile or cross-section method.

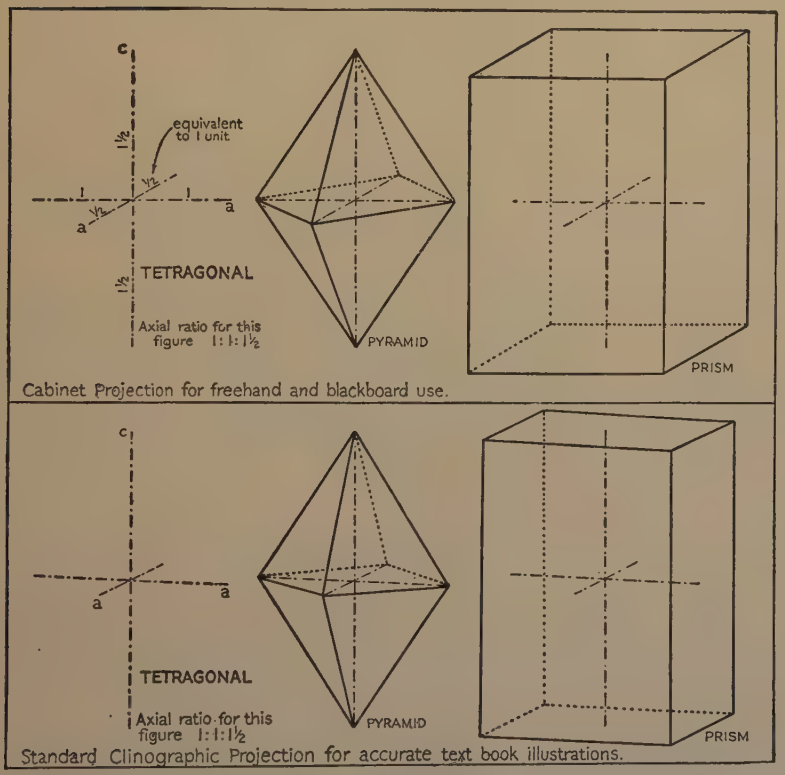


FIG. 275.—Tetragonal axes and crystal forms. Comparison between cabinet and clinographic projections.

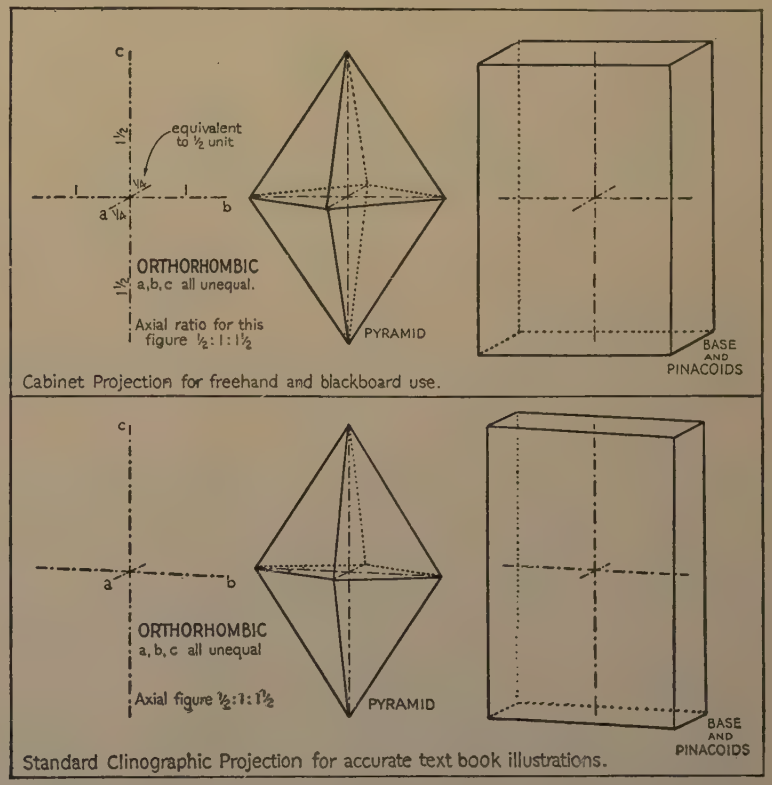


FIG. 276.—Orthorhombic axes and crystal forms. Comparison between cabinet and clinographic projections.

For the simpler forms, the attitude of the different faces will be best understood if the planes of these faces are drawn, as determined by their intercepts with the axes. In some instances it may be found helpful to start off with a cubical or rectangular block and slice off parts of the block to reveal particular planes. For example, in Fig. 277, a cubical block has been planed off so as to show two planes which are elements of a dodecahedron, having the symbols 101 and 011

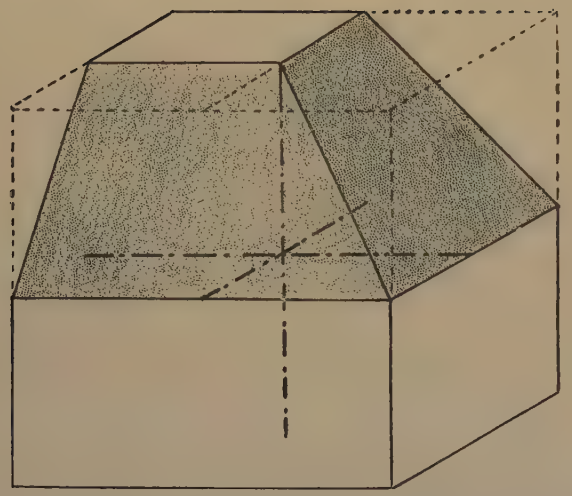


FIG. 277.—Cubical block with parts cut off to show position of planes 101 and 011, which are elements of a dodecahedron.

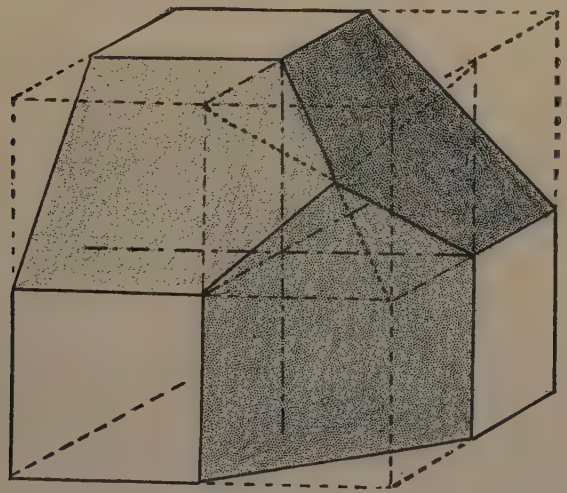


FIG. 278.—The cubical block illustrated in Fig. 277 after a third part has been removed to show the additional plane 110.

respectively. Each plane intercepts two axes and is parallel with the third. In Fig. 278 a third plane has been introduced, its intersections with the two other planes being determined in the same manner, as shown in Fig. 277. The further addition of planes, having the general formula 110, results in a complete dodecahedron. Figure 279 illustrates

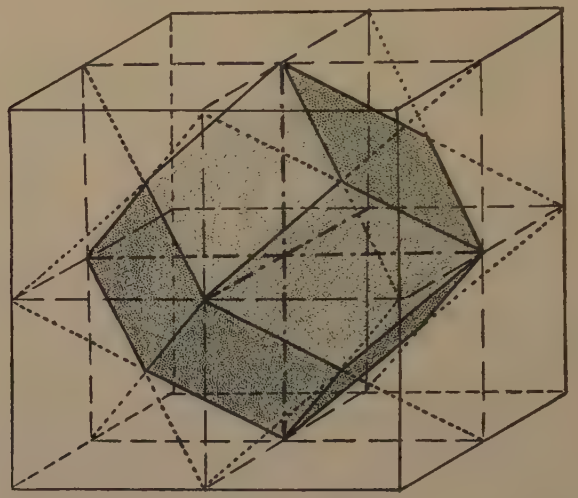


FIG. 279.—The same as Fig. 278 with all visible faces of the dodecahedron represented. All construction lines are shown. Each edge of the dodecahedron is determined by the intersection of two planes having the general formula 101, as in Fig. 277.

the construction lines used in drawing all the visible faces of the dodecahedron by the method of plane intersection.

In Fig. 279 it will be noted that the faces of the dodecahedron are parallelograms. This obviates the necessity of determining each time the direction of the edges. Once one edge is obtained many others may be drawn by sliding the

triangle along the T-square on a drawing board, thus using the method of parallelism.

Or again, it will be noted that the corners of the dodecahedron are either directly above or directly beneath other

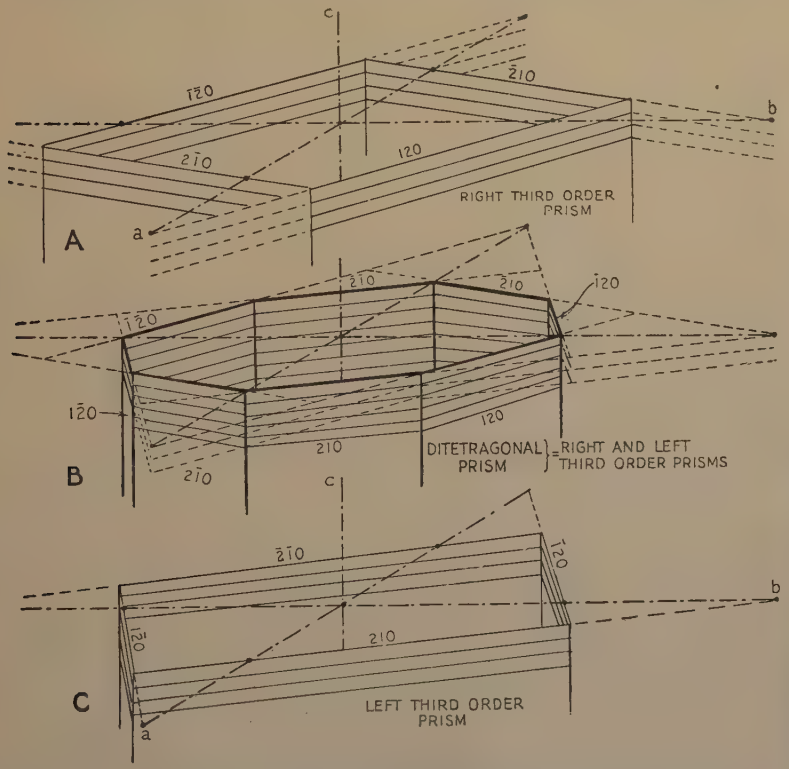


Fig. 280.—Right and left third order prisms shown separately and also combined to form ditetragonal prism.

corners because of the symmetry of the form. This assists in determining the position of several corners after one or two have been established. It illustrates the use of the

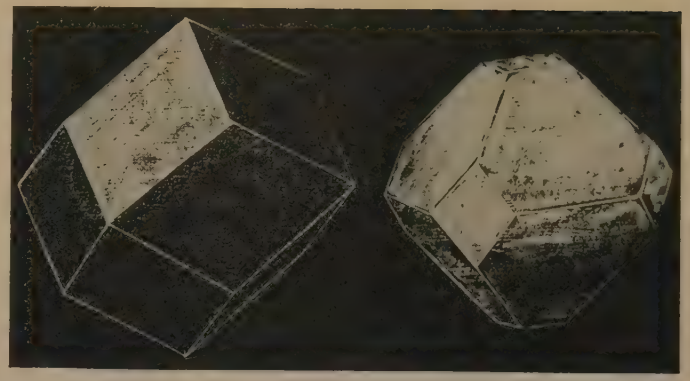


Fig. 281.—Blackboard drawings in cabinet projection showing (*a*) dodecahedron and (*b*) octahedron with cube. In blackboard drawing the use of the methods of parallelism and symmetry are especially helpful because such methods are so suited to freehand drawing. The shading of crystal forms in blackboard sketches is more readily accomplished than with most media. The light is imagined as coming from above and to the left.

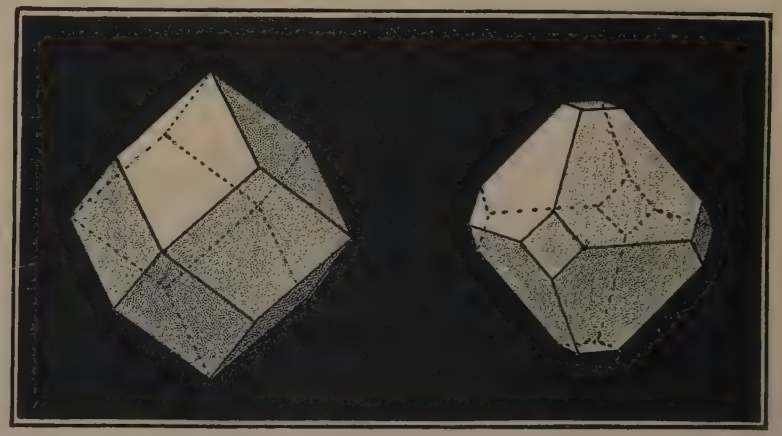


Fig. 282.—Pen and ink sketches with pencil shading of the forms shown in Fig. 281, drawn in standard clinographic projection.

method of symmetry, which may be applied to the drawing of many crystal forms.

Sometimes, in the case of rather complicated forms involving several kinds of faces, much help is gained by the use of a plan, or vertical cross-section, by which means certain dimensions are easily obtained. The procedure resembles the use of front and side elevations and plans in architectural drawing. This is the profile or cross-section method.

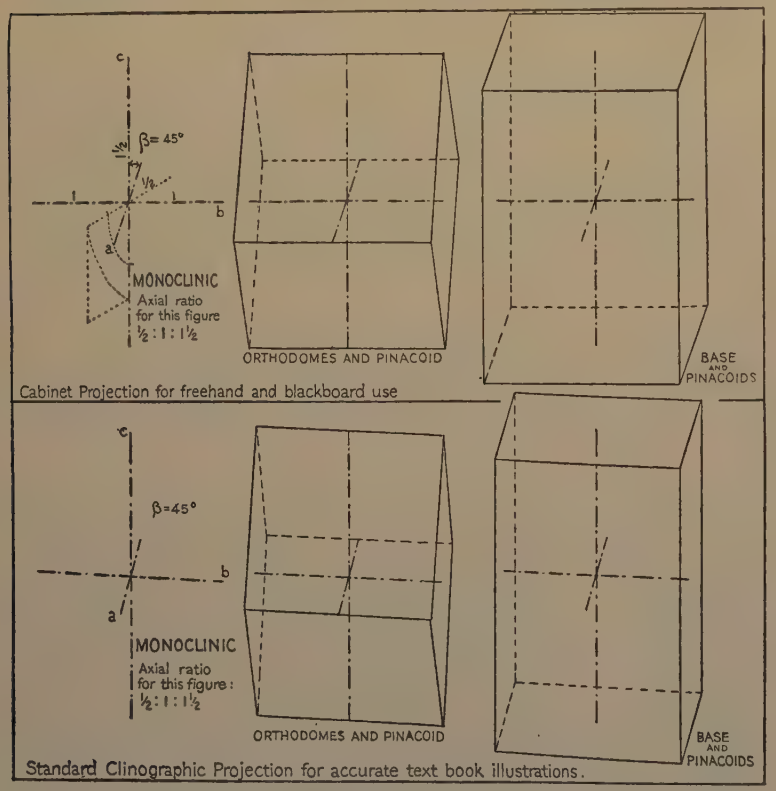


FIG. 283.—Monoclinic axes and crystal forms. Comparison between cabinet and clinographic projections.

Another application of the method of plane intersection is shown in Fig. 280. The right and left third-order prisms are shown separately, the prism faces being determined by the intersections with the *a* and *b* axes in the ratio of 2 to 1. The combination of the two forms produces the ditetragonal prism. A study of these figures, or better the preparation of

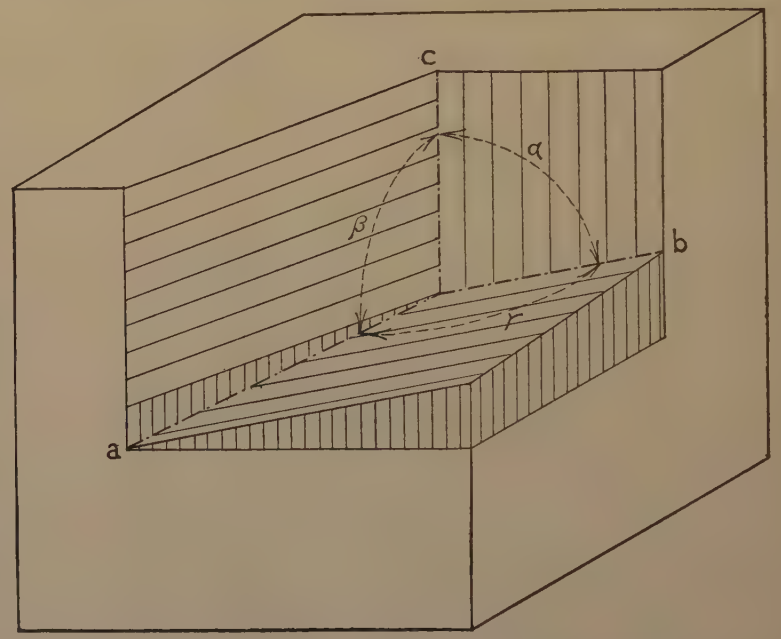


FIG. 284.—Triclinic axes shown in relation to a rectangular block drawn in cabinet projection. Usually the *a* axis is the shortest but in this case *b* is the brachy-axis, this being done for the sake of a better illustration.

such a drawing, does much to clear up in the mind of the student the essential character of the third-order forms with their lack of symmetry.

In general it will be found distinctly helpful in teaching, to shade the crystal faces in such a way as to suggest the

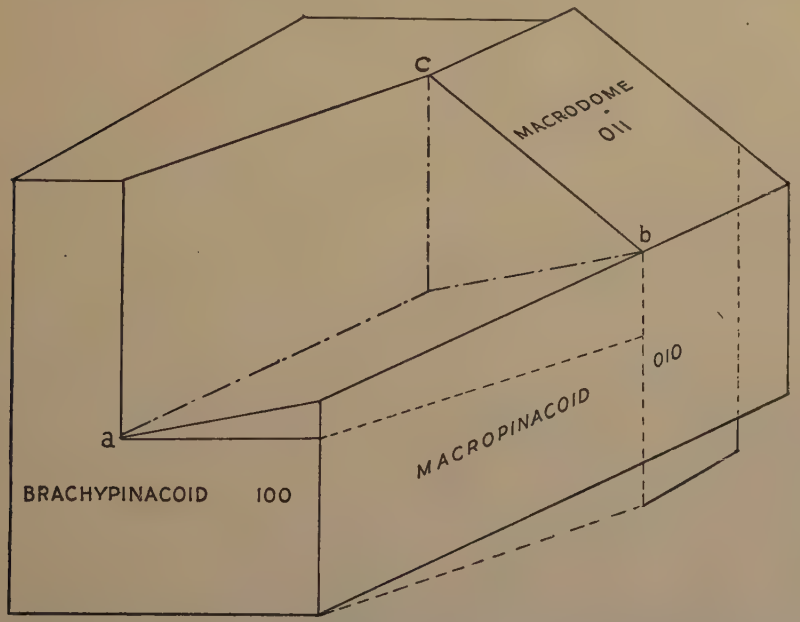


FIG. 285.—The block shown in Fig. 284, modified to show position of several crystal faces in relation to triclinic axes.

attitude of the different planes and thereby the shape of the crystal. If the light is imagined as coming from over one's left shoulder, as is usual in architectural rendering, then the crystal forms may be shaded somewhat as in Figs. 281 and 282. Figure 281 is a blackboard drawing in cabinet projection. In Fig. 282 the same forms are shown in standard clinographic projection for comparison.

143. Axes of the monoclinic system in cabinet projection.—Figure 283 shows the method of drawing the monoclinic axes in cabinet projection. The simplest way is to lay off the axes as for the tetragonal system . Next, measure

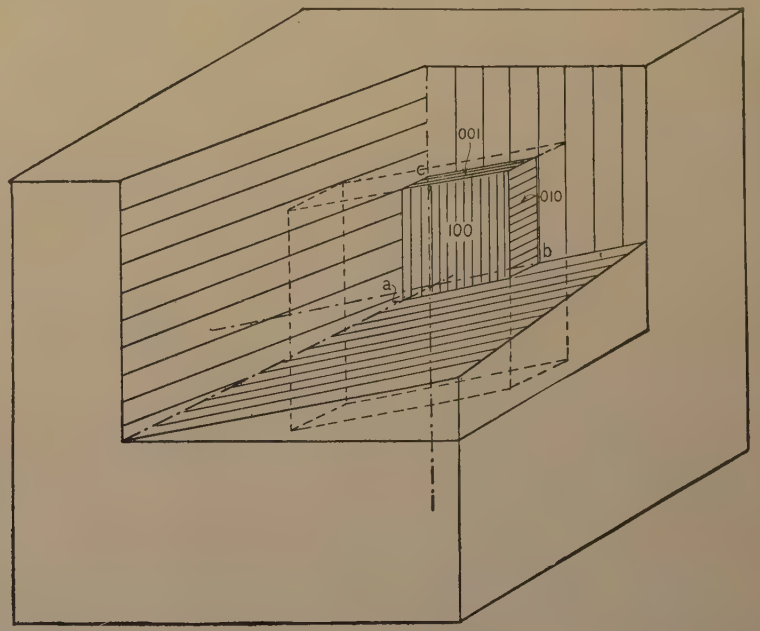


FIG. 286.—The block shown in Fig. 284, used as a means of displaying a simple triclinic form in order better to demonstrate the attitude of the faces with relation to each other. The axial ratio has been changed but the angles remain as in Fig. 284.

off the length of the *a* axis. That is, actually measure off one-half its length relative to the other axes, the *b* and *c* axes being drawn to their true relative lengths. The next problem is to swing the *a* axis around axis *b* as a pivot so that angle β (*beta*) is correct for the mineral species in ques-

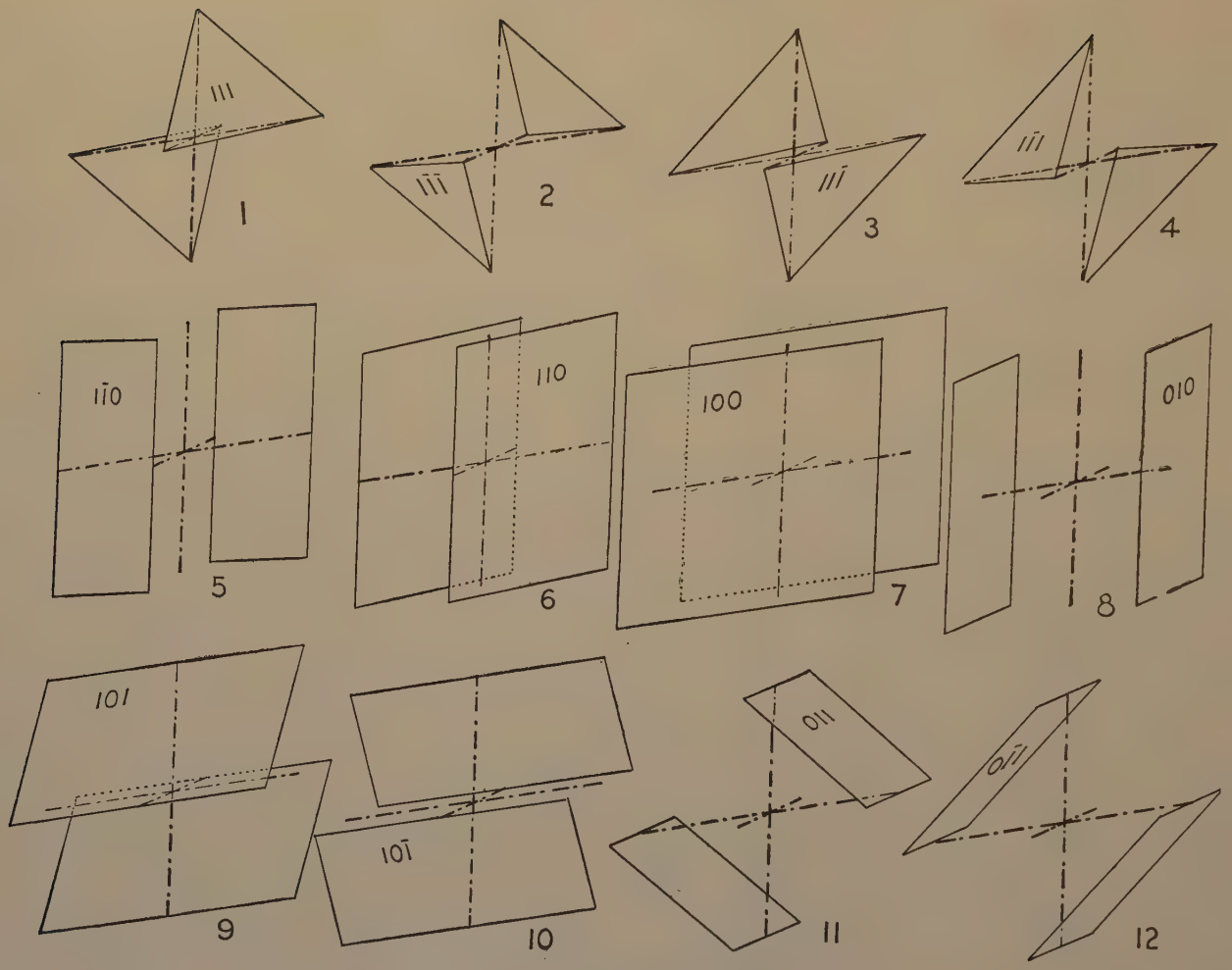


FIG. 287.—Faces of the triclinic system.

1. Pyramid (111)
2. Pyramid ($1\bar{1}\bar{1}$)
3. Pyramid ($11\bar{1}$)
4. Pyramid ($1\bar{1}1$)
5. Prism ($1\bar{1}0$)
6. Prism (110)
7. Macropinacoid (100)
8. Brachypinacoid (010)
9. Macrodome (101)
10. Macrodome ($10\bar{1}$)
11. Brachydome (011)
12. Brachydome ($0\bar{1}1$)

tion. The illustration shows clearly the procedure if β equals 45 degrees. With this simple operation as a guide, other angles for β can readily be laid out by eye with an unappreciable error.

144. Axes of the triclinic system in cabinet projection.—The simplest way of picturing the relation of three inclined axes to each other is to draw a rectangular block in cabinet projection and cut out the near corner along the triclinic axial planes, as shown in Fig. 284. The angles between the axes can be very closely represented by this means, and this is especially true for those triclinic forms having axial angles somewhere near 90 degrees. The lengths of the axes can easily be estimated by eye, sufficiently well for every practical purpose.

In Fig. 285, the block shown in Fig. 284 has been slightly modified, in order to represent the planes of several crystal faces. The drawing of such forms is aided materially by the use of the method of parallelism, especially in the drawing of domes and pinocoids where so many lines are parallel with the axes and have the same lengths as the axes. Figure 286 may suggest a further modification of Fig. 284 in which a crystal form consisting of pinacoids and base is shown in relation to a cubical block so that the attitude of the different faces can be better visualized. The axial ratio has been changed from that shown in Fig. 285, so that axis a becomes the brachy-axis.

In Fig. 287 the different faces of the triclinic system are shown as open forms in relation to their axes.

145. The hexagonal axes in cabinet projection.—Lay off first the tetragonal axes in cabinet projection, as in *A* of Fig. 288. Circumscribe an ellipse about these axes, drawing a square about them as an aid if desired, as in *B*. Then, keeping axis a_2 horizontal, draw in the two other a axes at 60-degree intervals. These may readily be estimated with the aid of diagonals at 45 degrees, as shown by the dotted

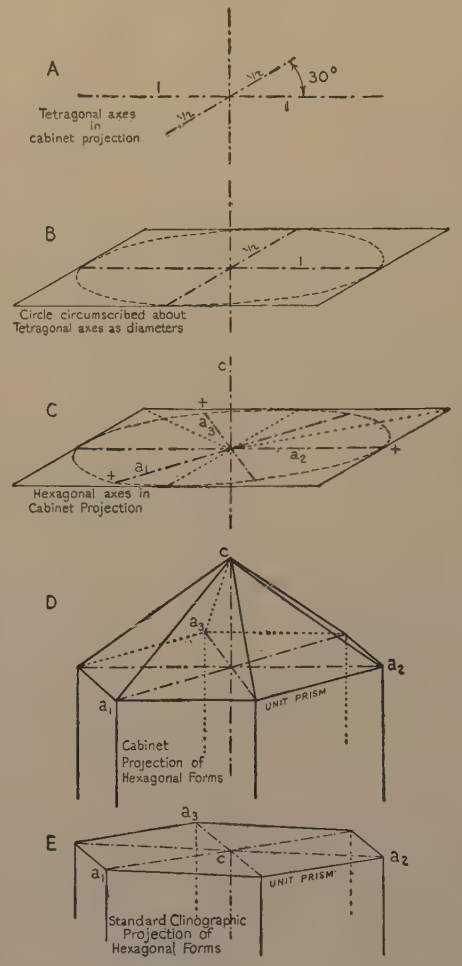


FIG. 288.—Hexagonal axes and crystal forms. Comparison between cabinet and clinographic projections.

lines in C. The drawing of crystal forms in the hexagonal system offers no unusual difficulties. The profile method, or use of plans and sections, will be found helpful in the case of combined forms.

EXERCISES

Based upon the Illustrations in Part V

Exercise 1. Indicate on Figs. 274, 275, 276, and 283 the symbols of all the faces, both visible and invisible.

Exercise 2. Using axes in cabinet projection, as in Figs. 274, 275, 276, and 283, prepare drawings of the commoner crystal forms and the simpler combinations. Make use of the methods suggested in Section 142.

Exercise 3. On Figs. 277, 278, and 279, indicate the symbols of all the crystal faces.

Exercise 4. On Fig. 278 introduce one more vertical plane $(1\bar{1}0)$, cutting off the left front corner of the cube.

Exercise 5. In Fig. 287 combine several or all of sketches 1, 2, 3' and 4 in order to make a solid figure. The invisible lines should be dotted.

Exercise 6. In Fig. 287 what faces must be combined with 9 and 10 to make a solid figure? Complete this form.

Exercise 7. With Fig. 287 as a guide, draw a crystal form using all the faces shown in 5, 6, 7, and 8.

Exercise 8. In Fig. 287, what forms must be combined with sketch 11 to give a solid?

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INDEX

Numbers refer to pages. Illustrations are indicated by an asterisk after page number.

Adirondack Mountains, maps, 91
Alabama, 158*
  topographical maps, 43,* 72, 159*
Albania, 163*
Aletschgletscher, 153,* 154*
Allegheny Front, 69,* 91
  Plateau, 2,* 69*
Alluvial fans, 101*
Alps, 153,* 154*
Angles, transferring, 25
Annular drainage, 55
Anticlinal mountain, 67*
  valley, 67*
Anticline, pitching, 65 , 66*
Appalachian ridges, 175,* 176*
Arizona, topographical maps, 43, 84, 160,* 161*
Arkansas, topographical maps, 72
Arrêtes, 110,* 111,* 112,* 113,* 114*
Austria-Hungary, topographical maps, 74, 105
Azores, maps of, 96

Barrier beach, 116*
Bighorn Basin, 56
Bird's-eye views, 2
Blackboard sketches, 185
Black Forest, 91
  Hills, 58*
Block basin, 84
  mountains, 76–85*
Bowman, Isaiah, referred to, 162
British Isles, 17,* 155*
  Ordnance Survey maps, 49,* 57,* 92, 112, 116*
Butte, 181*

Caldera, 93, 95,* 96*
California, topographical maps, 84
Canyon, 3,* 4,* 41,* 42,* 44,*
Chattanooga district, 159,* 183*
Cinder Cone, California, 95*
Cinder cones, 93
Cirques, 109, 109,* 110,* 111,* 112,* 113,* 114*
Coal seam, 2*
Coastal plain, 45, seq.
Colorado Plateau, 160,* 161*
  Rockies, 177*
  Springs district, *Frontispiece*
  topographical maps, 43, 59,* 60
Complex mountains, 89–92
Cone, 18,* 19*
  application of, 93, 109
Connecticut River, 107*
Consequent stream, 47*
Corners, elimination of, 3, 12
Crater lake, 93
Crystal drawing, 189–198
Cuestas, 47*
Cumberland Plateau, 159*
Cylinder, 18,* 19*

Davis, W. M., *drawings by*, 94,* 95,* 105,* 111,* 112,* 116,* 117,* 164,* 175,* 176,* 177*
  referred to, 40, 85, 93, 105, 108, 112, 115, 162, 176
Death Valley, 84
Delaware Water Gap, 175*
Dendritic drainage, 36,* 91
Dip, determination of, 123, seq.
Ditetragonal prism, 193*

Dodecahedron, 192*
Dome mountains, 53–60
Drill holes, problems involving, 121, seq.
Drowned rivers, 106
Dufour's method, 142

Ellipse, construction of, 134
Ellipses, application of, 116
England, Oxford region, 49*
  The Weald, 57*
Enlarging block, 24
Europe, 155*
European countries (see France, Germany, Austria-Hungary, Sweden, Switzerland, Norway, Great Britain, Italy)

Facets, triangular, 78,* 79*
Falls, 99, 100
Faulting, effect of, on tilted strata, 86,* 87*
Fault-line cliffs, 84
Finch, J. K., *illustrations from*, 167,* 168,* 170,* 172,* 174*
  quoted, 166, seq.
"Flatirons," 59*
Flood plains, 107
Folded mountains, 62–74
Folds, in geological cross-section, 11*
France, topographical maps, 50,* 73, 91
  part of northern, 164*

Garden of the Gods, *Frontispiece*
Geological cross-sections, 9

Georgia, topographical maps, 72, 159*
Germany, topographical maps, 51, 85, 91, 105
Glacial troughs, 112,* 113*
Glaciers, 109–114
Graben, 84
Grand Canyon, 160,* 161*
Great Britain, 17*
  Ordnance Survey maps, 49,* 57,* 92, 112, 116*
Grieves, L. V., *drawings by*, 166,* 169,* 170,* 173*
Gullies, 101*

Hayden Survey, *illustrations from*, 178,* 179,* 180
Hexagonal crystal system, 197*
Hogbacks, *Frontispiece*, 59*
Holmes, W. H., *drawings by*, 178,* 179,* 180*
Holyoke Range, 107*
Horizon, 22

Illinois, topographical maps, 43
Insequent stream, 47*
Instruments and materials needed, 20
Isometric crystal system, 190*
  projection, 119
Italy, Apennines and Val d'Arno, 176*
  Monte Argentario, 117*

Johnson, D. W., referred to, 115

Kentucky, topographical maps, 70*
Kittatinny Mountain, 175*

Lagoon, 116*
Lake Agassiz, 29
Landscape sketching, 165–186
Lava flows, 94,* 95*
Limestone, in geological cross-sections, 10*
Lookout Point, view from, 183*
Louisiana, topographical maps, 105, 107*

Mapping from landscape sketches, 171
Maryland, topographical maps, 35, 37
Massachusetts, topographical maps, 91, 101, 104,* 105, 107*
Materials and instruments needed, 20
Matterhorn peaks, 110
Mature plain, 35
  streams, 105
Mead, W. J., referred to, 134
Meander spurs, 32*
Meandering river, 31, 105
Minnesota, topographical maps, 29, 30*
Mississippi River, 107*
  topographical maps, 37, 105
Missouri River, 36*
Moccasin Bend, Tennessee River, 183*
Monoclinal mountain, 67*
  valley, 67*
Monoclinic crystal system, 194*
Montana, topographical maps, 112, 113, 114*
Monte Argentario, Italy, 117*
Moraine, 181*
Mountains, block, 76
  complex, 89
  dome, 53
  folded, 62
Mount Shasta, 185*
  Washington, 113,* 186*

Nebraska, topographical maps, 44
Nevada, topographical maps, 84, 84*
New England upland, 101
New Hampshire, topographical maps, 112, 113*
New Jersey coastal plain, 48*
  northern, 157*
  topographical maps, 48,* 72,* 91*
New Mexico, topographical maps, 42,* 60, 83*
New York State, topographical maps, 51, 91, 104*
Niagara cuesta, 51
  Falls, 104*
North Carolina, topographical maps, 35, 35*
North Dakota, topographical maps, 30*
Norway, topographical maps, 92

Obsequent stream, 47*
Old plain, 37
Oregon, topographical maps, 93
One-point perspective, 5
Orthorhombic crystal system, 191*
Outcrop, determination of, from drill holes, 136
  of dipping bed, 146*
  on irregular surface, 138

Palisades, 91, 157*
Paris Basin, 155,* 164*
Penfield, S. L., referred to, 189
Pennsylvania ridges, 175,* 176*
  topographical maps, 69,* 71,* 72,* 72, 91
  Wyoming Basin, 72*
Perspective, one-point, 5
  two-point, 22
Pikes Peak, *Frontispiece*
Plains and plateaus, 29–51
Plateaus, young, mature, and old, 39*
Poland, 162*
Presidential Range, 113,* 186*
Pyramid, 18,* 19*

Ramapo Mountains, 91*
Rapids, 99,* 100*
Reeks, Margaret, referred to, 189
Rejuvenated rivers, 108
Relief, by elevated contours, 138
  by elevated points, 151
Resequent stream, 47*
Rheims region, 50*
Rhine River, 105
River meanders, 105
Rock step, 114*
Rocky Mountains, 160*
  Mountain upland, *Frontispiece*, 177*

Sand dunes, 181*
Sections, cut out of block, 12
Shasta, Mount, 185*
Shorelines, 115

Silverton, Colorado, 184,* 185*
Sketching screen, 166
Sketch pad, 168
Smith, G-H., referred to, 50
South Dakota, topographical maps, 36,* 58*
Stream capture, 101, 103*
Streams, 97–108
Strike, determination of, 123, seq.
Submerged valley, 107*
Subsequent stream, 47*
Susquehanna Water Gap, 180*
Sweden, topographical maps, 51, 85, 92
Switzerland, topographical maps, 73, 113, 152,* 153,* 154*
Synclinal mountain, 67*
  valley, 67*
Syncline, pitching, 65, 66*

Taghanic Falls, Ithaca, N. Y., 182*
Tarn, 114*
Tennessee, topographical maps, 72, 159*
Terminal moraine, 181*
Tetragonal crystal system, 191*
Texas, topographical maps, 60
Third order prisms, 193*
Tombolo, 117*
Topographic quadrangles, drawing of, 14
Topography and structure, relation between, 1, 2
Torrential fans, 184*
Trellis drainage, 91
Triangular facets, 79*
Triassic Lowland, 91, 156,* 157*
Triclinic crystal system, 194*, 195*, 196*
Truncated spurs, 113*
Two-point perspective, 22

United States, eastern part, 156*
United States Geological Survey, *illustrations from*, 41,* 182,* 183,* 184,* 185*
United States Geological Survey topographic sheets—
  Alabama:
    Fort Payne, 72
    Scottsboro, 43*
  Arizona:
    Kaibab, 84
    Marsh Pass, 43
    Mount Trumbull, 84
  Arkansas:
    Little Rock, 72
  California:
    Furnace Creek, 84
  Colorado:
    Boulder, 60
    Colorado Springs, *Frontispiece**
    Danforth Hills, 60
    Grand Hogback, 59*
    Livermore, 60
    Mesa de Maya, 43
  Georgia:
    Fort Payne, 72
  Illinois:
    Macomb, 43
  Kentucky:
    Harlan, 70*
    Nolansburg, 70*
  Louisiana:
    New Orleans, 105, 107*
  Maryland:
    Denton, 35
    Hurlock, 35
    Patuxent, 37
    Wicomico, 35
  Massachusetts:
    Hawley, 91, 101, 104*
    Northampton, 105, 107*
  Mississippi:
    Iuka, 37
    Vicksburg, 105
United States Geological Survey topographic sheets—
  Montana:
    Chief Mountain, 113, 114*
    Nyack, 112
  Nebraska:
    Camp Clark, 44
    Goshen Hole, 44
    Scotts Bluff, 44
  Nevada:
    Carson Sink, 84
    Disaster, 84*
    Furnace Creek, 84
  New Hampshire:
    Mount Washington, 112, 113*
  New Jersey:
    Bordentown, 48*
    Cassville, 48*
    Delaware Water Gap, 72*
    New Brunswick, 48*
    Ramapo, 91*
    Sandy Hook, 48*
  New Mexico:
    San Pedro, 83*
    Watrous, 42,* 60
  New York:
    Carthage, 51
    Elizabethtown, 91
    Port Leyden, 51
    Highmarket, 51
    Kaaterskill, 91
    Lowville, 51
    Mount Marcy, 91
    Niagara Falls, 104*
  North Carolina:
    Falkland, 35
    Trent River, 35*
    Wilson, 35*
    Winterville, 35

United States Geological Survey topographic sheets—
North Dakota:
Fargo, 30*
Oregon:
Crater Lake, 93
Pennsylvania:
Catawissa, 72
Everett, 69*
Harrisburg, 71*, 72
Hollidaysburg, 69,* 91
Hummelstown, 72
Lebanon, 72
Lykens, 72
Mahanoy, 72
Millersburg, 72
Millerstown, 72
New Bloomfield, 71,* 72
Pine Grove, 72
Pottsville, 72
Shamokin, 72
Sunbury, 72
Wernersville, 72
South Dakota:
Black Hills region, 58*
Elk Point, 36*
United States Geological Survey topographic sheets—
Tennessee:
Chattanooga, 72
Texas:
Terlingua, 60
Utah:
Fish Springs, 84
Henry Mountains, 60
San Rafael, 60
Sevier Desert, 84
Tooele Valley, 84
Virginia:
Eagle Rock, 68*
West Virginia:
Greenland Gap, 73
Iaeger, 43
Wisconsin:
Kendall, 50
Mauston, 50
Sparta, 50
Tomah, 50
Winnebago, 50
Wyoming:
Cloud Peak, 59*
Fort McKinney, 59*
United States Geological Survey topographic sheets—
Wyoming:
Grass Creek Basin, 56
Meeteetse, 56*
Oregon Basin, 56
United States Hydrographic charts, reproduced, 96*
Utah, topographical maps, 60, 84, 161*

Vanishing points, 22
Vesuvius, 93
Virginia, topographical maps, 68*
Volcanoes, 93–96
Vosges Mountains, 91

Watchung Mountains, 157*
Waves, 115–117
Weald, 57*
West Virginia, topographical maps, 43, 73
White Mountains, 113,* 186*
Wisconsin, topographical maps, 50
Wyoming, topographical maps, 56, 56,* 59*

Yazoo River, 37
Young plain, 29, 35

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L79
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72-11